Coastal and Estuarine Water Quality State and Trends in Tāmaki Makaurau / Auckland 2024

State of the Environment Reporting

Janine Kamke and Jennifer Gadd

August 2025

Technical Report 2025/19

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Aerial photo of the Manukau Harbour, Auckland New Zealand. Photograph by Natalie Gilligan (EEMU).
Orcas in front of the Auckland Skyline in the Waitematā Harbour. Photograph by Janine Kamke (EEMU).

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Executive summary

This report is one of a series supporting the Auckland region's State of the Environment reporting. It provides regional and local coastal water quality updates to inform sustainable management, policy evaluation, and progress towards the Auckland Plan 2050 goals.

Coastal and estuarine water quality is monitored monthly at 31 sites across three main harbours, two large estuaries, and several Hauraki Gulf shoreline locations. We measure physical and chemical parameters, focusing on nutrients and water clarity, which can be influenced by land use, discharges, and seasonal or climatic variation.

We report on water quality state for a five-year period from July 2019 to June 2024. The trend reporting period for most parameters was reduced to a seven-year period from July 2017 to June 2024 due to the presence of step changes in the data associated with a change of laboratory in June-July 2017. Longer trend periods of 10 and 15-years up to June 2024 were included for parameters measured in the field. Comparison of the different trend periods indicated impacts of heavy rain events observed in the Auckland region in 2023 on the shorter trend period. Consequently, trend results for the seven-year period should be interpreted as indicative only.

Water quality was better at sites at the open-coast and at outer estuarine sites with high exposure to marine waters. At these sites water quality was generally rated as "good" or "excellent". Impact on water quality in the form of nutrient pressures and reduced water clarity became stronger at more sheltered estuarine sites with higher freshwater impact. At these sites water quality was largely classified as "fair". Water quality was poorest at sites closest to freshwater sources and sheltered areas in the upper estuaries. Water quality at these sites was most often classified as "marginal" or "poor". Overall water quality classifications either improved from or remained the same as previous reporting periods.

Trend results revealed signs of improvement in water quality at many sites across the region. More than 75 per cent of sites showed improving trends for total nitrogen, dissolved reactive phosphorus and turbidity. Ammoniacal nitrogen and total suspended solid trends were improving at more than 70 per cent of sites. Improving trends for chlorophyll *a* were found at more than half of all sites.

Individual water quality assessments for six areas in the region showed localised impacts on water quality with signs of nutrient pressures and/or low water clarity in the Manukau Harbour, the upper Waitematā Harbour and at the Kaipara River Mouth. Degrading trends for nutrient parameters were found for some sites in the Manukau Harbour and the upper Waitematā Harbour. At the Kaipara River Mouth, there were improvements in water quality, especially for water clarity parameters.

To better understand the extent of ecological impacts we recommend targeted investigations to characterise daily and seasonal fluctuations of algal growth and dissolved oxygen for areas showing signs of nutrient pressures.

Our report shows signs of influence on coastal water quality by climatic events, catchment activities, freshwater inputs, and marine processes. To identify specific drivers and support effective management, monitoring nutrient and sediment loads at terminal river reaches and adding oceanic water quality sites should be considered.

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1 Introduction

The marine environment in the Auckland region encompasses two oceans, three major harbours and numerous estuaries that collectively, include 75 per cent of the total area of the Auckland region. Within these are a wide variety of marine habitats which support a diverse range of plants and animals, including seaweeds, invertebrates, mangroves, seagrass, shellfish, marine mammals, fish, and sea birds.

The health, use, and aesthetics of coastal waters are shaped by a wide range of natural and human-driven factors. A key influence is the quality of surface water flowing from the land, including inputs from rivers, streams, overland flow, stormwater networks, and direct point source discharges to the coast. Activities within the coastal environment also contribute to water quality changes. Land use across the wider Auckland region and beyond affects coastal waters particularly in the Hauraki Gulf and Kaipara Harbour. Coastal water quality is further influenced by natural seasonal and long-term climatic variations. Physical processes like tides, currents, and wave action play a critical role in the transport and dilution of nutrients and contaminants, as well as the dispersal, settling, and resuspension of sediments.

Auckland Council's coastal and estuarine water quality monitoring programme focuses on nutrient and water clarity parameters. Other contaminants associated with urban land use and stormwater contamination, such as metals, are monitored in Auckland Council's river water quality, and estuarine sediment contaminants and ecology monitoring programmes and are not assessed here. Microbiological contamination of beaches and recreational water quality are monitored through the Safeswim programme, www.safeswim.org.nz .

This report provides technical information describing the current state of coastal and estuarine water quality and how it has changed over the past seven hydrological years (July 2017 to June 2024) across Tāmaki Makaurau/Auckland. This report is part of a series of technical reports collectively addressing river, groundwater, lake, and coastal water quality, and ecological condition over the same time frames. The current state of coastal and estuarine water quality (based on five hydrological years July 2019 to June 2024) can also be explored on the Water Quality and River Ecology Data Explorer (https://environmentauckland.org.nz/Data/Dashboard/456) and accompanying report (Kamke, 2025) but is summarised here to provide further context on trend directions, i.e. where water quality is good but declining, or poor but improving. This reporting is part of the feedback loop necessary to assess whether Auckland Council's management strategies are effective in sustaining ecosystem functions, and to identify opportunities for improved future sustainable use of our valued coastal environment. The information generated can also complement mātauranga Māori to support Māori in their role as kaitiaki to protect and enhance te mauri o te wai (the life supporting capacity of water).

1.1 Purpose and objectives

Auckland Council's coastal and estuarine water quality monitoring programme supports the following objectives:

- Meet council's obligations under section 35 of the Resource Management Act 1991 (as amended) to monitor and report on the state of the environment.
- Provide evidence of how the council is maintaining and enhancing the quality of the region's coastal environment (Local Government Act 2002). Specifically, evidence for the Environment and Cultural Heritage component of the Auckland Plan 2050. A key direction for the region is to manage the effects of growth and development on our natural environment.
- Help inform the effectiveness of policy initiatives and strategies and operational delivery.
- Assist with the identification of large scale and/or cumulative impacts of contaminants associated with varying land uses and disturbance regimes and links to particular activities.
- Provide baseline, regionally specific data to underpin sustainable management through resource consenting and associated compliance monitoring for coastal and estuarine environments.
- Continuously increase the knowledge base for Aucklanders and promote awareness of regional coastal and estuarine water quality issues and their subsequent management.

1.2 Supporting information

This report is one of a series of technical publications prepared in support of *Te oranga o te taiao o Tāmaki Makaurau – The health of Tāmaki Makaurau Auckland's Natural Environment in 2025: a synthesis of Auckland Council State of the Environment reporting*.

All related reports (past and present) are published on the Knowledge Auckland website.

All data supporting this report can be requested through our **Environment Auckland Data Portal**. Here you can also view live rainfall, river flow and air quality data and use several data explorer tools including the Water Quality and River Ecology Data Explorer.

2 Methods

2.1 Programme design

Auckland's coastal water quality monitoring programme was primarily designed for detecting long-term changes in water quality across the region. The monitoring network covers our three main harbours and several estuaries. It aims to be regionally representative by including monitoring sites that capture a range of contributing catchment land uses and varying exposure levels to open coastal waters, ocean swells and flushing times due to hydrodynamics and morphology (hereafter referred to as "exposure level"; see Table 2-1, Figure 2-1, and Figure 2-2). This enables Auckland Council to present a region-wide perspective on water quality and infer the likely water quality of other estuaries and coastal waters in the region that are not monitored. The programme currently includes 31 sites and has evolved over time, with sites added or removed according to varying regional management priorities.

Auckland Council's Environmental Evaluation and Monitoring Unit (EEMU) collects coastal and estuarine water quality samples monthly from surface waters. Sites in the inner Hauraki Gulf, Kaipara Harbour, Tāmaki Strait and Manukau Harbour are collected by helicopter, sites in the upper and central Waitematā Harbour are collected by boat and Tāmaki Estuary sites were collected from land up to January 2024 and are now collected by boat.

Natural temporal variation in water quality is avoided as much as possible by maintaining a consistent sampling time relative to the tidal cycle. Collection of water samples by helicopter enables sites spread over a broad area to be sampled within a narrow time window created by tidal constraints, making comparison between sites more robust. Samples were collected during the outgoing tide starting between 30 min and 123 minutes after high tide using the most appropriate tide gauge for each harbour. Over the past 15 years, more than 90 per cent of samples were taken between 9:00 am and 2:00 pm. Maintaining a consistent sample time improves the power of long-term trend detection. Due to the logistical sequencing of monitoring sites, the Kaipara Harbour is consistently sampled earlier in the day, and the Manukau Harbour later in the day. The time at which a sample is collected may affect some parameters, such as temperature and dissolved oxygen.

While sampling programmes are set up to be as consistent as possible, operational and strategic considerations have necessitated changes to site locations, run order and sampling times over the years. For the current reporting period there have been two notable changes. Firstly, the location of the Tāmaki sampling site was changed in 2019 when construction of the new North Pier at the Half Moon Bay Marina surrounded the original site with new breakwaters, making it unsuitable for future monitoring. Monitoring at an alternate site located at the end of the Half Moon Bay ferry terminal therefore commenced in July 2019, with dual analysis undertaken at both sites for a period of 18 months with minimal differences (Kelly and Kamke, 2023). Data from both sites are included in this report under the "Tāmaki" site name. Data until 30/06/2019 is from the Tāmaki at Half Moon Bay site, while data since 01/07/2019 is from the Tāmaki at Ferry Terminal location. Secondly, the run order of the Central and Upper Waitematā Harbour run was adjusted in March 2023 to better capture the influence of land-use effects, improve consistency in sampling on the outgoing tide and accommodate sampling at an additional site at Meola Reef (reporting for Meola Reef is expected in late 2026). Originally central harbour sites were sampled first and upper harbour sites last. This resulted in early sampling of the central harbour sites not fully catching the water of the ebb tide. Changing the run order and starting at the upper harbour sites and moving into the central harbour with the outgoing tide ensured all samples are now collected at ebb tide. While data comparison did not show strong differences between field parameters, this change has the potential to affect data ranges at central harbour sites and consequently trend analysis results.

Physical parameters such as temperature, salinity, and dissolved oxygen are measured in the field, and surface samples (~0.3m depth) are taken for further laboratory analysis of nutrients, water clarity parameters, and other chemical properties of water.

Further details on data collection and management are provided in the methodology report for the Water Quality and River Ecology Data Explorer (Atoa et al., 2025). A summary of laboratory analytical methods for each parameter is provided in Appendix A.

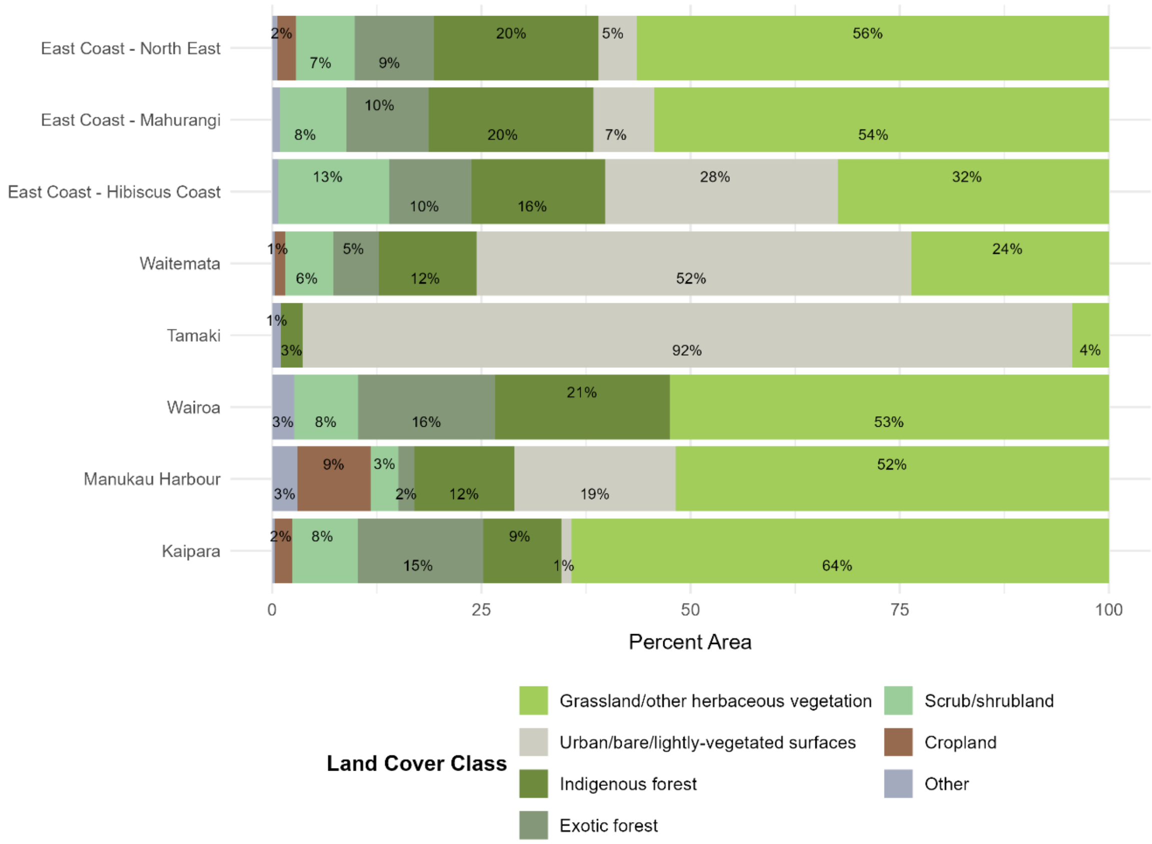

Figure 2-1. Summary of broad land cover classes within each watershed, based on Auckland Council (2025).

Table 2-1. Current coastal and estuarine water quality sites grouped by location.

	Site	Easting	Northing	Year initiated	Exposure Level	Dominant adjacent land use*
East Coast	Goat Island/Rakiriri	1761787	5984944	1993	Open Coast	Rural*
	Ti Point	1760058	5978931	1991	Open Coast	Rural*
	Mahurangi Heads	1754225	5960548	1993	Estuary	Rural*
	Dawsons Creek	1753782	5966175	1993	Estuary	Rural*
	Orewa	1753660	5949837	1991	Open Coast	Urban *
	Browns Bay	1757497	5935771	1991	Open Coast	Urban *
Kaipara Harbour	Shelly Beach	1723871	5952426	1991	Estuary	Rural*
	Kaipara River	1725504	5947101	2009	Estuary	Rural
	Makarau Estuary	1727396	5953730	2009	Estuary	Rural
	Kaipara Heads	1708534	5970421	2009	Estuary	Rural*
	Tauhoa Channel	1717821	5970063	2009	Estuary	Rural*
	Hōteo River	1726691	5967495	2009	Estuary	Rural
Waitematā Harbour	Chelsea	1753721	5922776	1991	Estuary	Urban*
	Whau Creek	1748588	5920563	1991	Estuary	Urban
	Henderson Creek	1746715	5923855	1991	Estuary	Urban
	Hobsonville	1749453	5927353	1993	Estuary	Urban
	Paremoremo Creek	1745717	5930201	1993	Tidal Creek	Lifestyle/Native Forest
	Rangitopuni Creek	1742734	5930626	1993	Tidal Creek	Rural
	Brighams Creek	1742829	5928227	1996	Tidal Creek	Urban
	Lucas Creek	1749892	5932176	1993	Tidal Creek	Urban
Tāmaki Estuary	Tāmaki	1769303	5916944	1992	Estuary	Urban*
	Panmure	1765553	5913693	1992	Estuary	Urban
	Wairoa River	1786561	5910769	2009	Estuary	Rural
Manukau Harbour	Grahams Beach	1749431	5897517	1987	Estuary	Urban/Rural*
	Clarks Beach	1749746	5888100	1987	Estuary	Rural
	Waiuku Town Basin	1752923	5879195	2012	Estuary	Rural
	Shag Point	1748335	5908549	1987	Estuary	Urban/Rural

	Site	Easting	Northing	Year initiated	Exposure Level	Dominant adjacent land use*
Manukau Harbour	Puketutu Point	1753938	5908791	1987	Estuary	N/A
	Weymouth	1764080	5897952	1987	Estuary	Urban/Rural
	Māngere Bridge	1758048	5910932	1987	Estuary	Urban
	Manukau Heads	1741520	5900335	2009	Estuary	Urban/Rural*

* Open coast and main harbour body/harbour mouth sites are less subject to direct influences from adjacent land use

Figure 2-2. Location of the 31 coastal and estuarine water quality monitoring sites.

2.2 Reporting periods

Coastal water quality data is impacted strongly by environmental conditions, sampling procedures and analysis techniques. Subtle changes in the environment due to land-based activities may be masked by technical changes in the programme. Methods and procedures for data collection and analysis change with new technologies and differing resource management priorities. Therefore, programme changes and laboratory analysis changes are not avoidable for monitoring programmes including some 30 years of data such as the coastal water quality SOE programme. The aim of this report is to include time periods with the greatest technical consistency for most sites and parameters, so data was assessed for consistency prior to state and trend analysis.

In 2009, changes to the coastal water quality SOE monitoring programme came into effect after a programme review. These changes included the addition of several monitoring sites included in current reporting (Table 2-1), as well as implementation of improved field data documentation and data management. To ensure consistency, data collected before July 2009 was excluded from all analysis.

Known changes in laboratory analysis methods have occurred since 2009 (see Appendix A) with effects on data continuity at most sites (Table 2-2). Data was inspected visually including difference in median, variance and trend slope to assess the effect of these changes (see Appendix B for example plots) and resulted in clear or likely step changes for several parameters (Table 2-2). Recent advice for paired sampling provides information to calculate offsets over such changes for trend analysis (Wood, 2024). However, paired data for these calculations were either not available or of insufficient length to complete the analysis.

Table 2-2. Known changes in laboratory analysis methods since 2009.

Date	Change	Parameters affected
October 2015	Adjustment to calibration standard for the analytical instrument at the laboratory	Total nitrogen
July 2017	Change of laboratory services provider from Watercare Laboratory Services to Hill Laboratories	Total nitrogen, Ammoniacal nitrogen, Dissolved reactive phosphorus, Total phosphorus, chlorophyll *a*, Total suspended solids
December 2020	Change of analytical instrument at the laboratory	Total phosphorus

Consequently, analysis periods for this report were adjusted to exclude data affected by step changes and provide the most consistent reporting period for all sites and parameters. This report includes state analysis for a standard reporting period of five hydrological years from July 2019 to June 2024. Trend analysis is often conducted for 10-year periods or longer because shorter time periods are more likely to be influenced by climatic variability and particular weather events (Snelder et al., 2021). For this report the trend analysis period for most parameters was reduced to a seven-year trend period including data from July 2017 to June 2024. Total phosphorus was not included in trend analysis. Extreme weather events occurred during the seven-year period (Section 3) and have the potential to skew trend results. Seven-year trend results should therefore be considered preliminary only and confirmation of trend results is highly recommended once sufficient consistent data is available for a longer period. Ten and 15-year trends (hydrological years 2015 to 2024 and 2010 to 2024, respectively) were analysed for field-collected parameters and compared to seven-year trends in the regional overview (Section 3) and in area specific chapters where applicable.

2.3 State analysis

Data requirements, processing and analysis followed the same procedure as described previously (Atoa et al., 2025) and is summarised briefly below.

State analysis was based on hydrological years, encompassing 12 months starting in July and ending in June the following calendar year. The end year of the hydrological year is referred to in the text (e.g. the hydrological year 2020 starts in July 2019 and ends in June 2020). Summary statistics were calculated over a period of five hydrological years.

All data included in this report was quality checked according to Auckland Council's internal quality standards for data up to 2020 and according to the National Environmental Monitoring standards (NEMS) for coastal water quality (NEMS, 2020) from 2020 to 2024. Poor quality data was excluded from analysis and reporting.

For the calculation of summary statistics data availability was checked against minimum data requirements for each monitoring site and parameter combination. Minimum data requirements applied to each reporting period were 80 per cent of monthly samples over the selected reporting period and 80 per cent of years for the selected reporting period. For example, a five-year reporting period requires 48 samples from a minimum of four hydrological years.

Censored data (above or below the detection limit of the analytical method) was corrected as follows: left censored data (below the method detection limit) was adjusted by imputation using Regression Order Statistics (ROS) according to Larned et al. (2015). Right censored data (above the method detection limit) were imputed by survival analysis following Helsel (2012). The adjusted data was used for generating all figures and tables showing state summary statistics. Data adjustment, statistical analysis and preparation of data illustrations was conducted in R (R Core Team, 2025) and R Studio (Posit team, 2025) using the analysis package provided by Land Water People Ltd (Fraser and Snelder 2025).

2.3.1 Coastal water quality guidelines and Water Quality Index

There are no water quality thresholds or guidelines for coastal and estuarine waters in New Zealand that have a formal legal status or are widely agreed upon. Such thresholds are difficult to determine because the individual water bodies' morphological, hydrological and other characteristics result in variable susceptibility, for e.g. nutrient enrichment and sediment impacts. Despite these challenges, guideline comparisons remain a valuable tool. They provide context for interpreting water quality data and enable more objective assessments across different sites, time periods, and regions. In this report, we compared water quality state results to a range of guideline values from various sources (Table 2-3).

We included both localised and default guideline values based on the recommendations of the Australian and New Zealand Environment and Conservation Council (ANZECC). The use of localised guideline values is considered preferable, but if these cannot be established ANZECC default guideline values can be used in the interim (ANZECC, 2000). In either case it is recommended to compare the median of the test site data to these guidelines (ANZECC, 2000).

- Localised guidelines for open coastal and estuarine sites in Auckland were developed by Foley (2018), using the 80th percentile (upper thresholds) and 20th percentile (lower thresholds) of ten years of data (2007-2016) from two open-coastal sites and three estuarine sites, which were considered the "least modified sites" in the region. These were compared to ANZECC default values, and the more permissive of the two was used for reporting.
- Tidal creek guidelines were derived by Ingley and Groom (2022), based on the 90th percentile of data from three estuarine reference sites, and supplemented by relevant Northland Regional Council values (Griffiths, 2016).
- Total nitrogen and total phosphorus were assessed using ANZECC (2000) default guidelines.

It is important to note that localised guideline values were established using data collected prior to the method changes described in Section 2.3. This can impact comparison of post-step change data to these guidelines as follows:

- Lower measurements after the method changes result in more stringent guidelines (e.g., ammoniacal nitrogen at tidal creek sites).
- Higher measurements after the method changes lead to more lenient guidelines (e.g., chlorophyll *a* across all exposure levels, and dissolved reactive phosphorus at estuary and open-coast sites).

To maintain consistency in future reporting, localised guidelines should be reviewed once sufficient post-method change monitoring data become available.

We also included guideline values for dissolved oxygen and chlorophyll *a* based on recent recommendations to the Ministry for the Environment (MfE) for estuarine indicators (Stevens et al., 2024). These thresholds reflect concentrations at which critical ecological states are likely to occur.

- Dissolved oxygen thresholds were proposed for the seven-day-mean minimum based on high frequency data but their use as conservative thresholds for discrete monitoring data was suggested, along with more intense investigation as a consequence of a breach of this value. The threshold for a 'poor' ecological status was included in this report as an additional dissolved oxygen guideline. It indicates the transition from moderate oxygen stress on aquatic organisms to significant and persistent stress (Stevens et al., 2024).
- Chlorophyll *a* thresholds reflecting peak phytoplankton bloom conditions were proposed by Stevens et al. (2024) using the 90th percentile of monthly data. The suggested thresholds for 'poor' ecological status were included as guidelines in this report, with different values for euhaline systems (open coast) and meso/polyhaline systems (estuaries and tidal creeks).

Guidelines were included in state reporting in two ways:

1. Regional Summary (Section 3): We calculated a Coastal Water Quality Index (WQI) by comparing guidelines to the monthly median for a five-year time periods as outlined by Kelly and Kamke (2023). The WQI was calculated for the current state reporting period (hydrological years 2020-2024) and, for comparison over time, two previous reporting periods hydrological years 2015-2019 and 2018-2022 using consistent methods. It is important to note that the 2015-2019 reporting period includes step changes described above (Section 2.2), and results should be interpreted with caution. The WQI assigns an overall grade from 'excellent' to 'poor' and considers:

- Number of parameters exceeding guidelines at least once
- Percentage of samples exceeding guidelines
- Magnitude of exceedance

For consistency with previous reporting (e.g. Kelly and Kamke, 2023, Ingley and Groom, 2022), WQI scores were calculated using a subset (underlined in Table 2-3) of all guidelines included in this report. Score ratings are explained in Table 2-4. The WQI provides a broad overview rather than site-specific insights.

2. Local Assessments (Sections 4-9): We compared current state results to all guidelines listed in Table 2-3. Exceedances prompted more detailed investigation of potential pressures or recommendations for additional monitoring, in line with ANZECC (2000). Where five-year median values approached but did not exceed guidelines, monthly statistics were reviewed to assess seasonal exceedances.

Table 2-3. Water quality guidelines used for state assessment. Unless otherwise stated guidelines were derived from the 80th percentile of 10 years of data (2007-2016) at sites assumed most likely representing reference conditions in the Auckland region (Foley, 2018). Guidelines used for the calculation of the Water Quality Index are underlined.

Parameter	Condition	Creek Guideline	Estuary Guideline	Coast Guideline
Ammoniacal Nitrogen (mg N/L)	median below	0.018 [A]	0.015 [B]	0.015 [B]
Total Oxidised Nitrogen (mg N/L)	median below	0.047 [C]	0.029 [C]	0.027 [C]
Total Nitrogen (mg/L)	median below	0.3 [C]	0.3 [C]	0.12 [C]
Dissolved Reactive Phosphorus (mg P/L)	median below	0.021 [D]	0.021	0.012
Total Phosphorus (mg/L)	median below	0.03 [C]	0.03 [C]	0.025 [C]
Chlorophyll *a* (mg/L)	median below	0.0039 [A]	0.0031	0.0023
Chlorophyll *a* (mg/L)	90th percentile below	0.016 [E]	0.016 [E]	0.012 [E]
Dissolved Oxygen % Saturation	median between	80 – 110 [D]	90 – 110 [C]	90 – 110 [C]
Dissolved Oxygen (mg/L)	minimum above	5 [F]	5 [F]	5 [F]
Turbidity (NTU)	median below	10 [C]	10 [C]	1 [C]

[A] Based on the 90th percentile of estuary reference sites from the Auckland region.

[B] Based on ANZECC default guideline for ammonium not ammoniacal nitrogen. At the average pH of seawater, approximately 95 per cent of ammoniacal nitrogen is in the ammonium form.

[C] Based on ANZECC default guideline values from mildly disturbed ecosystems (ANZECC 2000).

[D] Based on Northland Regional Council Tidal Creek Guidelines (Griffiths, 2016).

[E] Based on recommended threshold for phytoplankton biomass (as chlorophyll *a*) for moderately impacted ecological communities (Stevens et al., 2024).

[F] Based on recommended threshold for ecologically moderate stress on aquatic organisms (Stevens et al., 2024).

Table 2-4. Water Quality index scores and interpretation.

WQI Class	Score range	Meaning
Excellent	95-100	Water quality is protected with a virtual absence of threat or impairment, conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within guidelines all the time.
Good	80-94	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels or water quality guidelines.
Fair	65-79	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels or water quality guidelines.
Marginal	45-64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels or water quality guidelines.
Poor	0-44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels or water quality guidelines.

2.4 Trend analysis

2.4.1 Data requirements and time periods for analyses

Monotonic trends were assessed for the seven-year period from July 2017 to June 2024 (Section 2.2). For field parameters additional trend analysis for the 10-year period from July 2014 to June 2024 and 15-year period from July 2009 to June 2024 were completed. Minimum data requirements for trend analysis were applied for all trend periods. Each site-parameter combination required at least 80 per cent of samples per year (for non-seasonal trend analysis) or season (for seasonal trend analysis). Furthermore, over the total trend period 80 per cent of years or seasons were required for analysis. For example, over a 10-year period of monthly monitoring, this is equivalent to at least 10 samples per year in at least eight of the 10 years. Any sites or parameters that did not meet these data requirements were not analysed and therefore no trends were reported.

2.4.2 Analysis methods

Trend analysis was conducted in R (R Core Team, 2025) and R Studio (Posit team, 2025) using the analysis package provided by Land Water People Ltd (Fraser and Snelder 2025) which is based on Snelder et al. (2022).

Briefly, data were assessed for seasonality using the Kruskal-Wallis test which determined the application of seasonal or non-seasonal trend assessment for each site-parameter combination. It detects statistically significant seasonal data patterns with flexible definition of season, including any period from monthly, bimonthly, quarterly or biannually (annually would be considered non-seasonal) over a total of 12 months. The best fit is determined automatically. Monotonic trends across sites were analysed by assessing the direction of a trend (i.e. is the parameter increasing or decreasing?). The confidence in the trend direction was calculated using the Kendall or seasonal Mann-Kendall test based on the probability that the trend was decreasing. In seasonal tests, water quality observations were compared within each season over time and summed for each season. In non-seasonal tests, all water quality observations were compared over time. The calculated probability for a decreasing trend is interpreted based on the categories used by the Intergovernmental Panel on Climate Change and further aggregated to five categories for simplicity as per LAWA (Cawthron Institute 2019; Fraser and Snelder 2018) (see Table 2-5). A trend is classified as low confidence when there is insufficient evidence to determine if the data is trending in a particular direction. If there was a large proportion of censored values (<5 non-censored values and/or <3 unique non-censored values) or if there was no, or very little variation, or poor precision in the data resulting in ties (equal values), trends were recorded as "not analysed".

For most parameters, a decreasing trend is interpreted as an improvement in water quality, and an increasing trend is a degradation in water quality. For physical parameters such as temperature, pH, dissolved oxygen and salinity we have referred to the likelihood of the direction of the trend as increasing or decreasing and have not assigned this as either improving or degrading.

Table 2-5. Trend confidence category levels used to determine the direction of trends.

Trend categories		Probability (%)
Very likely improving	Very likely decreasing	90-100
Likely improving	Likely decreasing	67-90
Low confidence	Low confidence	33-67
Likely degrading	Likely increasing	10-33
Very likely degrading	Very likely increasing	0-10

Where water quality is found to be degrading further assessment is critical to understand what actions may be necessary to improve water quality. This includes assessment of the likelihood of the trend, the magnitude of the trend, the risk of adverse ecological outcomes (in relation to the known current state), and consideration of whether the current state is a reflection of naturally occurring processes.

The magnitude of the trend is characterised by the slope of the trend line using the Sen slope estimator (SSE) (or the seasonal version (SSSE)). The SSE is the median of all possible inter-observation slopes. The 90 per cent confidence intervals of this median estimate were also calculated (Fraser & Snelder, 2025).

While a trend may be very likely improving or degrading, the smaller the Sen slope, or rate of change, the longer it would take to be reflected in assessments of the current state assuming a linear rate of change. The confidence in the direction of the trend and estimation of the magnitude of the trend decreases in reliability as the proportion of censored values increases. The Sen slope may be zero where there is a high proportion of censored data or non-unique (referred to as "tied") non-censored values in the dataset.

3 Regional Overview

3.1 Climate summary 2010 to 2024

Both the Interdecadal Pacific Oscillation (IPO) and El Niño Southern Oscillation (ENSO) are strong drivers of New Zealand's climate and coastal conditions. These cycles affect average sea surface temperature, prevailing winds, and rainfall patterns. This drives differences in nutrient and sediment concentrations through changes to oceanic upwelling of nutrient rich waters, and land-based discharges from soil erosion and nutrient leaching. La Niña events typically bring more rain, warmer sea waters and higher sea levels to the northeastern areas of the North Island, while El Niño events bring drier conditions and cooler waters (Pearce et al. 2018).

Large oscillations between El Niño and La Niña cycles occurred between 2010 and 2024. La Niña conditions prevailed in 2010-2011 and an extended La Niña period occurred from August 2020 to March 2023. El Niño events were recorded in 2015-2016, 2019 and June 2023 to May 2024. This resulted in higher-than-normal rainfall in 2011, 2016 to 2018 and between 2022 and early 2024. The latter period included the heavy rain events during the Auckland Anniversary floods and Cyclone Gabrielle in summer and autumn 2023 (Johnson 2021, NIWA 2024, 2025). Lower than normal rainfall in the Auckland region was observed during 2010, 2014, 2019 and in late summer and autumn of 2024 (Johnson 2021, NIWA 2025). These variations in rainfall can be expected to affect coastal water quality. Coastal and estuarine water quality monitoring is undertaken at monthly intervals and is not specifically designed to capture high rainfall and river flow events although these are occasionally intercepted (Ingley, 2020).

Notable was also the occurrence of several marine heatwave events which caused ecological stress to marine organisms (in particular in the Hauraki Gulf) (Shears et al., 2024) and can impact nutrient cycles and phytoplankton growth. Strong marine heatwaves occurred in the Auckland region in 2017 to 2018, 2021 to 2022 (2022 being the warmest year on record) and early 2024 (Shears et al., 2024).

3.2 State across the region

Water quality of coastal waters around the region was highly influenced by location and the degree of mixing between freshwater and sea water. The location of monitored sites ranged from open coast to harbours and estuaries, and tidal creeks – each of which differed in terms of the influence of freshwater. These differences could be most clearly seen in physical parameters such as salinity, an indicator of the mix of freshwater and sea water. The open coast sites showed the lowest variation in salinity over the five-year period, with salinity consistently between 32 and 35 ppt at each site. In contrast, sites in tidal creeks showed the greatest variation in salinity, ranging from nearly freshwater (<2 ppt) through brackish (2-12 ppt) to seawater (~35 ppt). Salinity at the estuary monitoring sites varied widely between sites, reflecting diverse geomorphological and hydrodynamic conditions in the estuaries. Upper and mid-estuary sites (e.g., Henderson Creek, Hōteo River Mouth) experienced greater variation in salinity than outer estuary sites, at harbour mouth and closer to the coast (e.g., Chelsea, Manukau Head, Kaipara Heads).

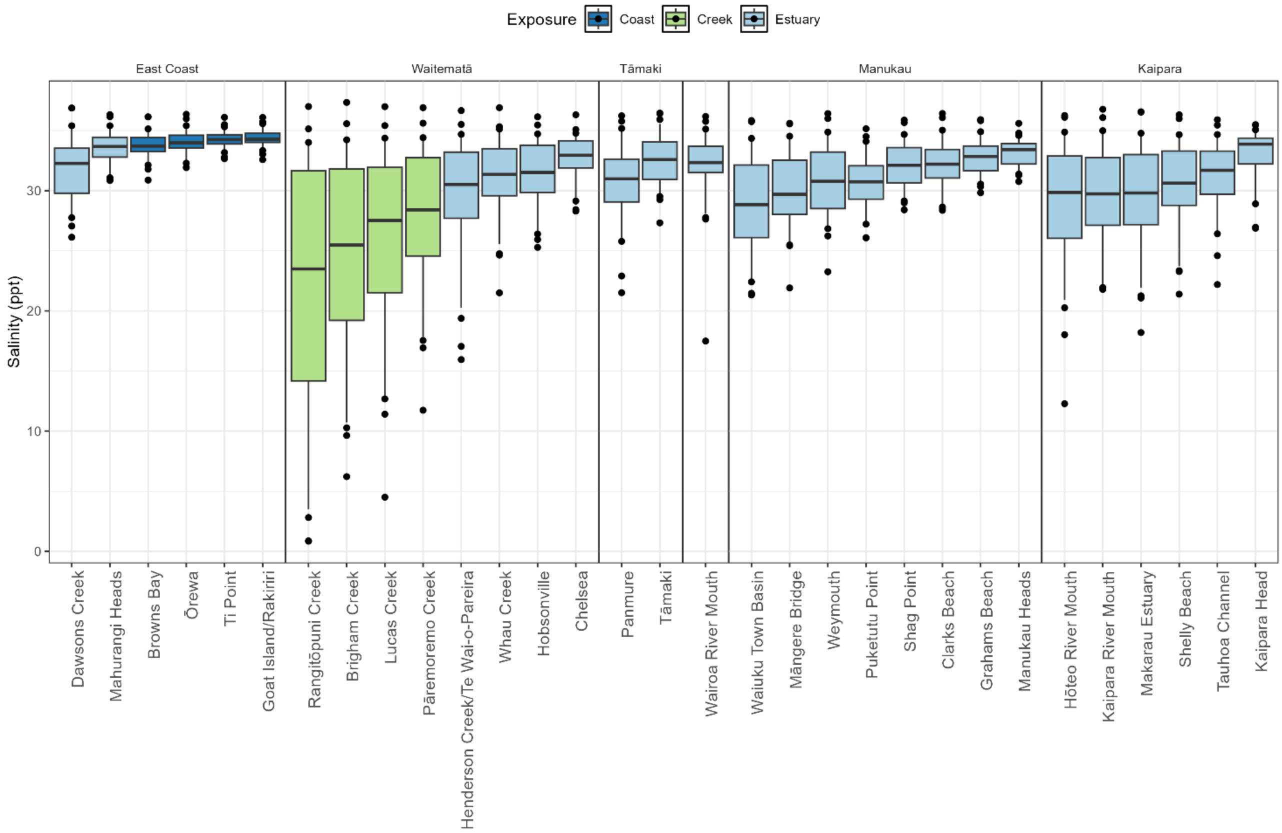

Figure 3-1. Variation in salinity between and across each of the monitoring sites. Data from 2020 to 2024.

In general, sites with more freshwater influence have higher concentrations of contaminants delivered via freshwater, including nutrients and sediment (Dudley et al., 2020). Coastal sites with less freshwater influence typically have better water quality. This is evident in the water quality index (WQI) scores which summarise water quality state based on nutrients, clarity and dissolved oxygen indicators (Table 3-1, Figures 3-2 and 3-3).These findings were consistent with previous reporting where salinity was identified as a main driver of the water quality index scores, despite the use of separate guidelines for tidal creek, estuarine and open-coastal environments (Ingley, 2020).

All open coast sites were classed as having 'Good' water quality based on the data from hydrological years 2020 to 2024. There were four sites with 'Excellent' water quality, all of which were estuary sites located in outer estuarine areas with higher tidal flushing than other estuary sites. A class of 'Excellent' indicates that all measurements were consistently within guideline values for this five-year monitoring period.

There were five sites with 'Poor' water quality and a further five sites with 'Marginal' water quality – located within the upper arms of estuaries or in tidal creeks (Figure 3-3). The WQI scores for all tidal creek sites were classed as 'Marginal' or 'Fair', with no sites attaining 'Good' or 'Excellent' water quality. These findings confirm modelling predictions of higher nutrient concentrations in these upper estuary arms (Dudley et al., 2024).

The guideline values used for the calculation of the WQI differ between exposure types (coastal vs estuary vs creek; see Table 2-3), so an estuary site classed as 'Excellent' may not have lower nutrients or higher water clarity than a coastal site classed as 'Good'. The WQI should be interpreted as a broad classification only. We address spatial differences in water quality for each area in more detail in Sections 4-9.

Improvements in WQI scores were seen at many sites in the current reporting period compared to the last reported period for the WQI from 2018 to 2022 and from 2015 to 2019 (the closest reporting period of the last state and trends report)[1]. Only one site degraded in its WQI score, Ti Point at the East Coast, but remained in the “good” grade. No degradation was indicated in the WQI grades at any other site for the current reporting period and sites that did not improve in overall grade remained at least at the same score (Table 3-1).

Details on the water quality state are presented and discussed in the following sections for each harbour or area.

[1] The last state and trends report (Ingley, 2021) included a shorter time period over 3 calendar years compared to 5 hydrological years. For better comparison WQI results were calculated for the corresponding 5 hydrological year period.

Table 3-1. Coastal Water Quality Index Scores across the current and two previous reporting periods. Exposure type shown in parentheses OC = Open Coast, E = Estuary, TC = Tidal Creek. WQI class: Blue = Excellent, Green = Good, Yellow = Fair, Orange = Marginal, Red = Poor.

		2015 - 2019	2018 - 2022	2020 - 2024
East Coast	Browns Bay (OC)	79	69	80
	Dawsons Creek (E)	90	90	100
	Goat Island/Rakiriri (OC)	90	81	81
	Mahurangi Heads (E)	90	90	100
	Ōrewa (OC)	90	90	90
	Ti Point (OC)	81	90	81
Kaipara	Hōteo River Mouth (E)	66	69	69
	Kaipara Head (E)	90	81	100
	Kaipara River Mouth (E)	40	40	42
	Makarau Estuary (E)	65	58	67
	Shelly Beach (E)	68	69	70
	Tauhoa Channel (E)	71	71	90
Manukau	Clarks Beach (E)	46	47	48
	Grahams Beach (E)	70	70	70
	Māngere Bridge (E)	26	28	30
	Manukau Heads (E)	81	71	71
	Puketutu Point (E)	28	30	36
	Shag Point (E)	39	42	52
	Waiuku Town Basin (E)	25	28	28
	Weymouth (E)	39	41	42
Tāmaki	Panmure (E)	45	59	68
	Tāmaki (E)	69	69	70
Wairoa	Wairoa River Mouth (E)	70	80	90
Waitematā	Brigham Creek (TC)	48	39	50
	Chelsea (E)	80	90	100
	Henderson Creek/Te Wai-o-Pareira (E)	70	71	80
	Hobsonville (E)	61	81	90
	Lucas Creek (TC)	51	61	70
	Pāremoremo Creek (TC)	51	61	61
	Rangitōpuni Creek (TC)	46	38	49
	Whau Creek (TC)	89	90	90

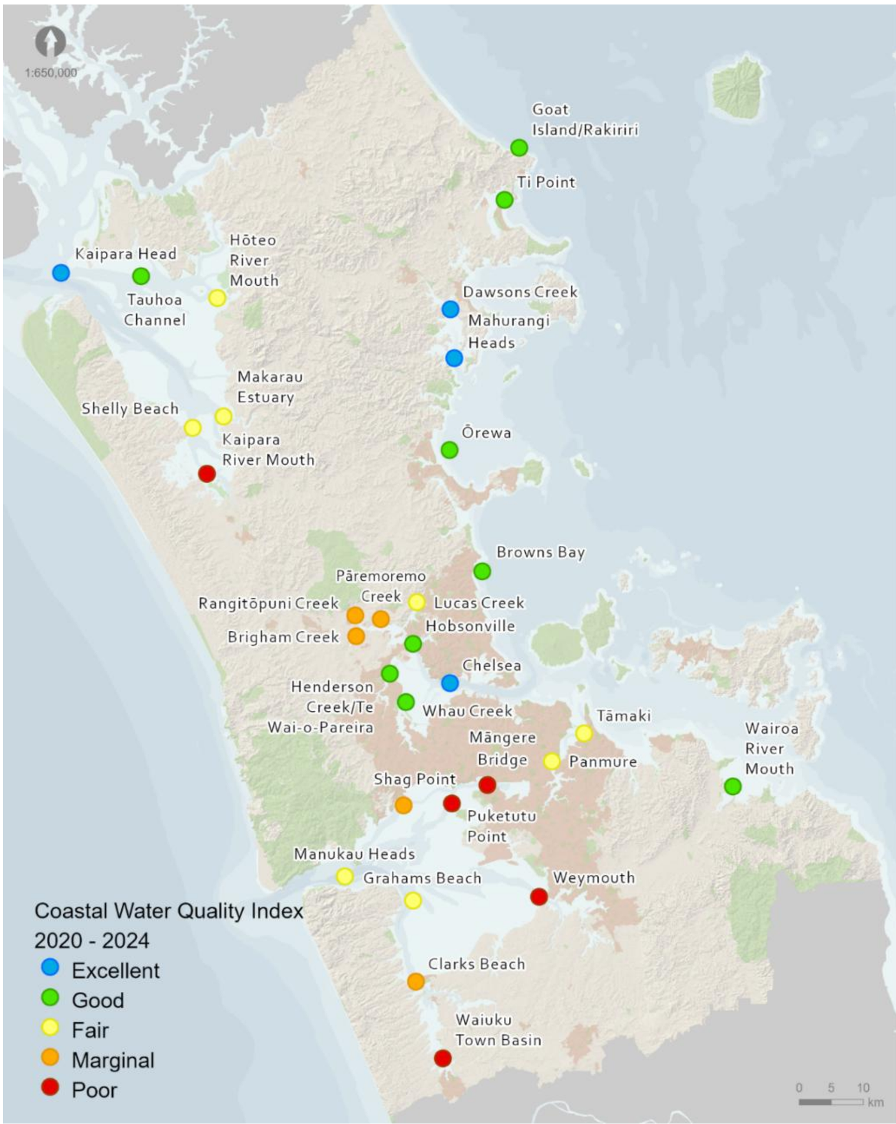

Figure 3-2. Water Quality Index classes for all monitoring sites across the Auckland region based on data collected from 2020 to 2024.

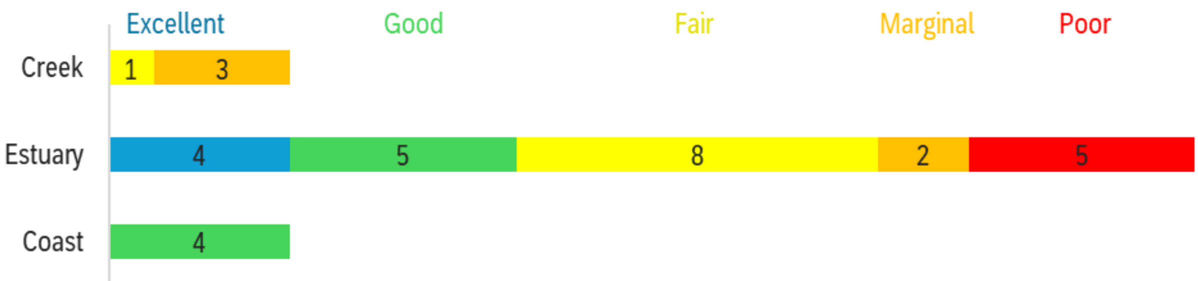

Figure 3-3. Number of sites in each class of Water Quality Index scores for 2020 to 2024.

3.3 Trends across the region

Salinity and pH decreased from hydrological years 2018 to 2024 at almost all sites across the region (Figure 3-4), with no sites demonstrating increasing trends in these two parameters (there was low confidence in the trend direction for salinity at two of the 31 sites). These decreasing trends may be a result of the lower than normal rainfall in 2019-2020 (near the start of the trend period) and higher than normal rainfall in 2022 through to early 2024 (end of trend period; Lorrey et al., 2025). The higher rainfall delivers higher than usual freshwater flows to the estuaries, harbours and coasts which mixes with the sea water and reduces the salinity. Time series plots of the salinity data show a clear decrease in salinity around 2022-2023 which affects the seven-year trends (see Figure 3-5 for an example for the Shelly Beach site). The sea water pH (global surface water average 8.05-8.1, Law et al., 2017) is higher than that of freshwater, so these increased freshwater inputs also decreased the pH at our monitoring sites.

It is likely that the climatic conditions and increased freshwater inflows also influenced other variables measured in the coastal and estuarine waters. For example, water temperature also decreased at around a third of sites over the seven-year period, with likely increases at only four sites and low confidence in the trend direction for most sites. This decrease may be due to the freshwater inflows or cooler than normal autumn temperatures in 2023 and 2024 (NIWA 2024; 2025).

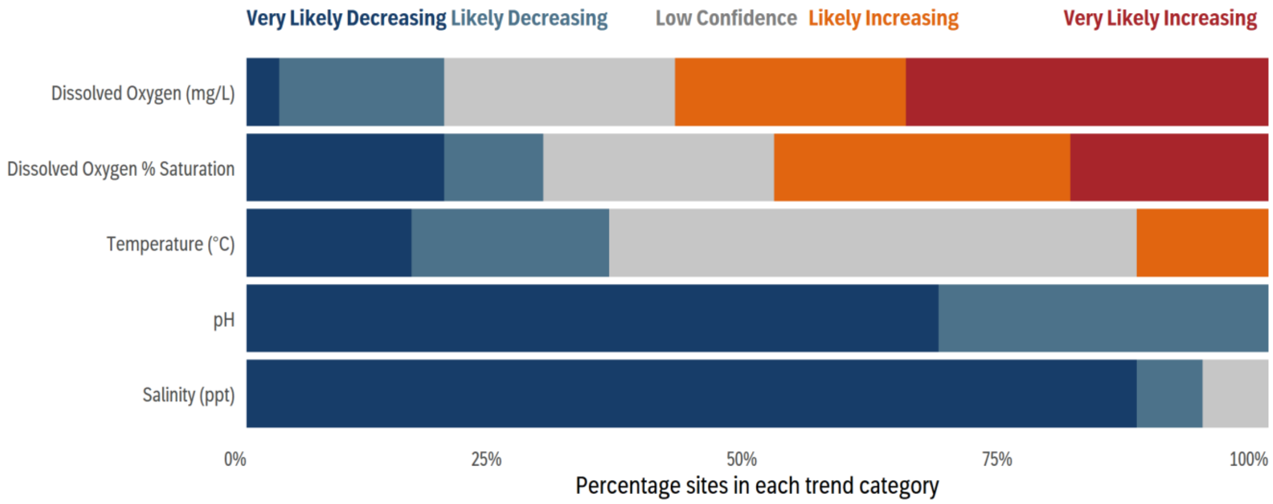

Figure 3-4. Summary of the trend direction and confidence for physico-chemical parameters measured across all sites monitored in the Auckland region.

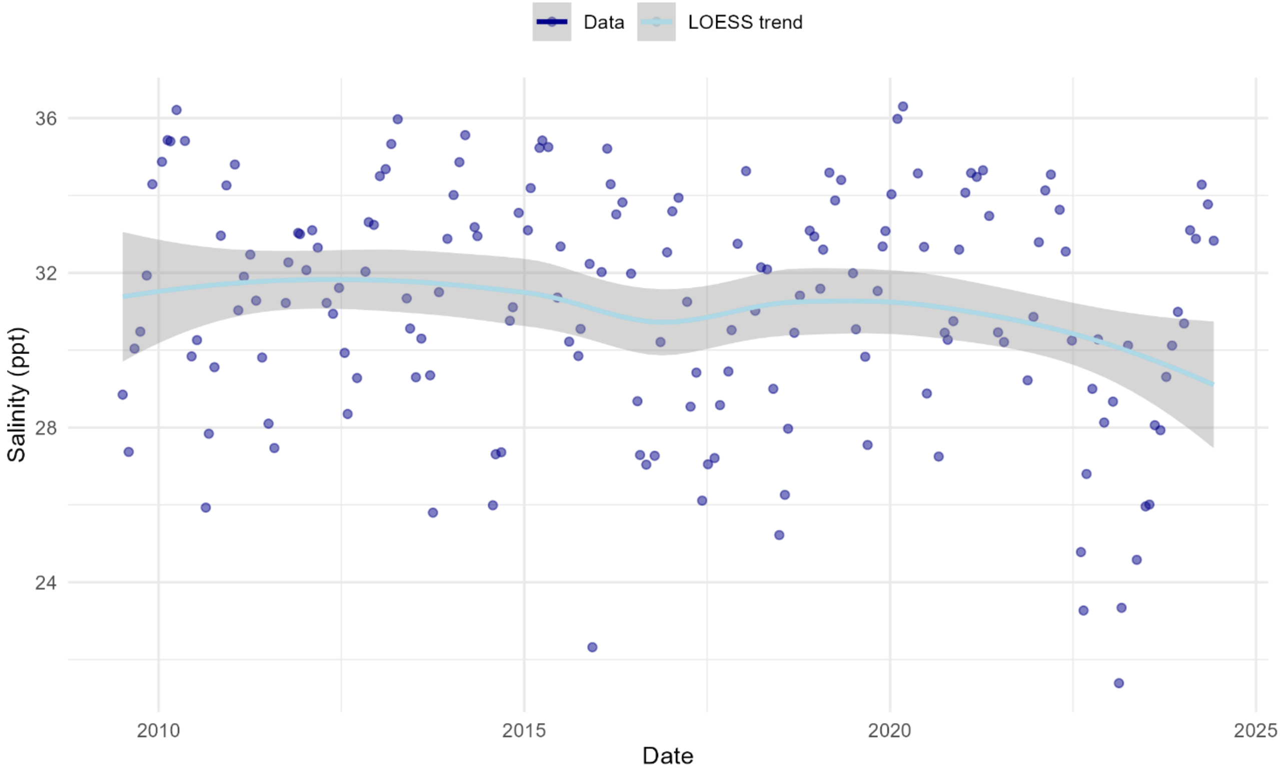

Figure 3-5. Timeseries of salinity measurements with LOESS trend at Shelly Beach monitoring site.

Across the region, concentrations of most nutrients decreased at most sites over the seven-year period assessed (Figure 3-6). In particular, dissolved reactive phosphorus decreased at more than 80 per cent of sites indicating improvements in phosphorus in the coastal waters. These decreasing trends also occurred over longer timeframes, although there is some uncertainty due to changes in laboratory methods. Decreasing trends in phosphorus at multiple sites were also reported in the previous state and trends analysis (Ingley, 2021). For total nitrogen there were more sites with decreases over seven-years than increases. These decreases are despite the higher rainfall in 2023, when total nitrogen was generally above the site average, as expected with increased freshwater flows delivering additional nutrients and sediment. This suggests a general improvement in total nitrogen across the region. A previous national assessment of coastal water quality reported mainly increases in total nitrogen at sites in the Auckland region (Fraser et al. 2021). However, that assessment did not consider the effect of the laboratory method change which resulted in a step change in the total nitrogen concentrations and influenced results across all sites (see Section 2.2.). Including data outside of the Auckland region, Fraser et al. (2021) found that most total nitrogen trends in New Zealand up to 2020 were decreasing, which matches the findings of this report.

In contrast, for total oxidised nitrogen, which includes the soluble and bioavailable forms of nitrogen, there were 12 sites with increasing concentrations (degrading water quality) and 11 sites with decreasing concentrations (improving water quality). Many of the sites with degrading total oxidised nitrogen were located in tidal creeks or inner arms of the Waitematā and Manukau Harbours and may have been influenced by the higher freshwater inputs in 2022 and 2023. Findings for the Waitematā and Manukau harbours are discussed further in Sections 5 and 8 respectively.

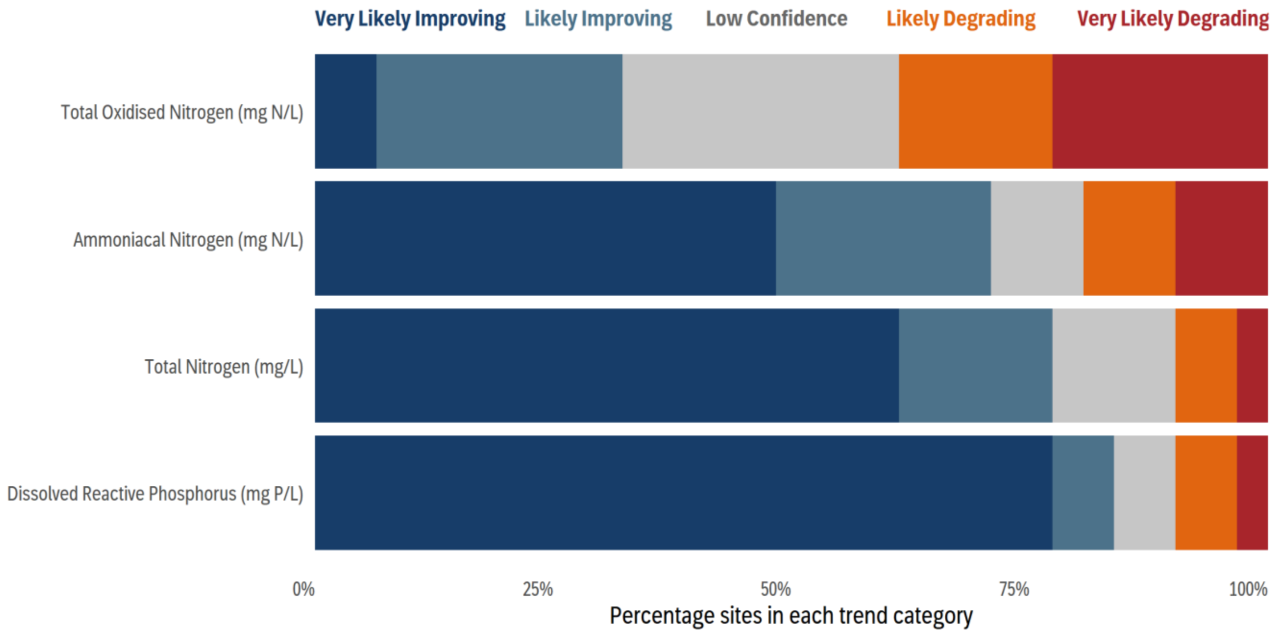

Figure 3-6. Summary of the trend direction and confidence for nitrogen and phosphorus parameters measured across all sites monitored in the Auckland region.

Chlorophyll *a*, a measure of the amount of phytoplankton or microscopic algae in waters. While phytoplankton is an important component of the food chain excessive growth is considered a sign of nutrient enrichment and can cause further adverse ecological effects. Decreasing trends in chlorophyll *a* are therefore considered an improvement in water quality., Chlorophyll *a* improved (decreased) at more than half the sites, whereas degrading trends were measured at around 25 per cent of sites. The improvements across the region are consistent with previous reporting of improving trends at most sites from 2010 to 2019 (Ingley, 2021). Chlorophyll *a* is likely to be influenced by climatic variables including water temperature, salinity and associated mixing patterns but also light and nutrient availability. There were, however, some sites in the Waitematā Harbour where chlorophyll *a* increased, along with one or more forms of nitrogen and/or phosphorus. These will be discussed further in Section 5.

Similarly, turbidity and total suspended solids decreased (improved) at most sites, with increases only at one and four sites respectively. This may seem unexpected given the higher flows and storms of 2023 that resulted in erosion and slips, but reflects the dynamic nature of estuaries, harbours and coastal environments.

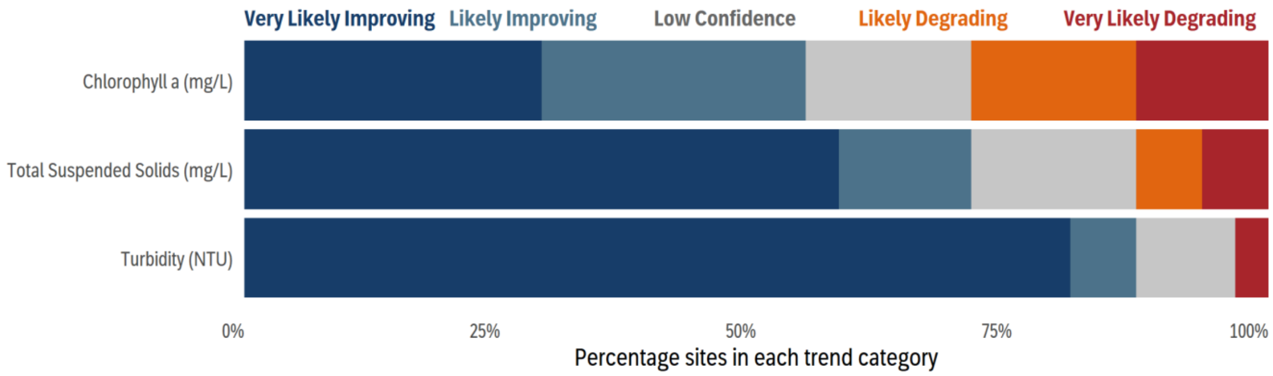

Figure 3-7. Summary of the trend direction and confidence for water clarity related parameters measured across all sites monitored in the Auckland region.

The water quality trends described above are based on a reduced period of seven years. These seven-year trends are susceptible to natural variability caused by variations in climate (Snelder et al., 2021). El Niño-Southern Oscillation (ENSO), which contributes significantly to the inter-annual variability of weather systems in Auckland, operates on a quasi three-to-seven year timescale. Trends in water quality are ideally assessed over a period that is long enough to reduce the effect of ENSO – such as 10-years or more. However, as described in Section 2.2, changes in the laboratory methods resulted in step-changes in measured results that were not related to environmental conditions. These step changes cannot easily be assessed using the statistical methods most commonly used for water quality trends in New Zealand[2].

For parameters that we measure in the field we can assess trends over multiple time periods. Trends were assessed across three time periods: seven years (July 2017 to June 2024), 10 years (July 2014 to June 2024) and 15 years (July 2009 to June 2024). This assessment shows that salinity decreased over all time frames (Figure 3-8). The rate of the decreasing trends (annual Sen slope) was consistently lower for 15 and 10-year trends (site average annual Sen slopes: -0.2 and -0.3 ppt, respectively) compared to seven-year trend (site average annual Sen slope: -0.6 ppt). The higher-than-normal rainfall throughout 2023 resulted in lower-than-normal salinity at many sites which influenced trends, with the shortest trend period affected most strongly. Decreasing trends in salinity from 2010-2019 were previously reported across most sites (Ingley 2021).

For other field parameters, the trends over a longer time period differ in direction from those over a shorter time period, which are more affected by climate. For example, while temperature decreased at most sites over the recent seven-year period, it has increased over a 15-year period. The broader increase over 15 years is consistent with air temperatures between 2019 to 2024 being some of the warmest national average temperatures and multiple occurrences of marine heatwaves over this period (Lorrey et al., 2025).

Similarly, pH decreased at all sites over the seven-year period but at most sites there were increases over the longer 10 and 15-year periods. The decrease in the shorter and more recent time period is likely driven by the higher freshwater flows (with lower pH than sea water) associated with the higher than normal rainfall in 2022 through to early 2024 (end of trend period; Lorrey et al., 2025). Increasing pH trends were found at more than 70 per cent of coastal water quality sites in New

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[2] Alternative methods that can account for laboratory changes could be used to assess trends, however we use methods that are consistent with those used for freshwater and with national initiatives like LAWA.

Zealand in assessments up to 2020 (Fraser et al., 2021). It is important to note that the resolution of pH sondes used by Auckland Council and commonly used in state of the environment monitoring in New Zealand is 0.1 pH unit. Average trend magnitudes for pH in this report ranged from 0.005 to 0.009 pH units. Therefore, pH trends in this report should be considered indicative at best. Notable also is that the precision of the pH sonde is insufficient for the assessment of ocean acidification effects. The variability of pH in coastal water is generally much higher than in oceanic waters and specialised methodology is needed to assess finer scale changes as those described in ocean acidification studies (Law et al., 2017).

Both measures of dissolved oxygen showed somewhat different results for the different time periods. For the seven-year period, there were more sites with increasing trends than decreasing, whereas for the 15-year period there were more sites with decreasing trends than increasing. Low trend magnitudes over all time periods indicated slow rates of change which are susceptible to changing trend direction over different time periods.

Shorter time periods for trend assessment can be appropriate for understanding the effect of recent changes in management or environmental conditions (Snelder et al., 2021). Because of the laboratory method changes, for most parameters we cannot assess trends over a period longer than seven-years with our current trend method. However, as demonstrated above, the shorter time periods are more influenced by climate variation and have lower statistical power (due to fewer observations) meaning more ‘low confidence’ trend results. It is important to consider these limitations when interpreting the trends presented and discussed in subsequent sections of this report.

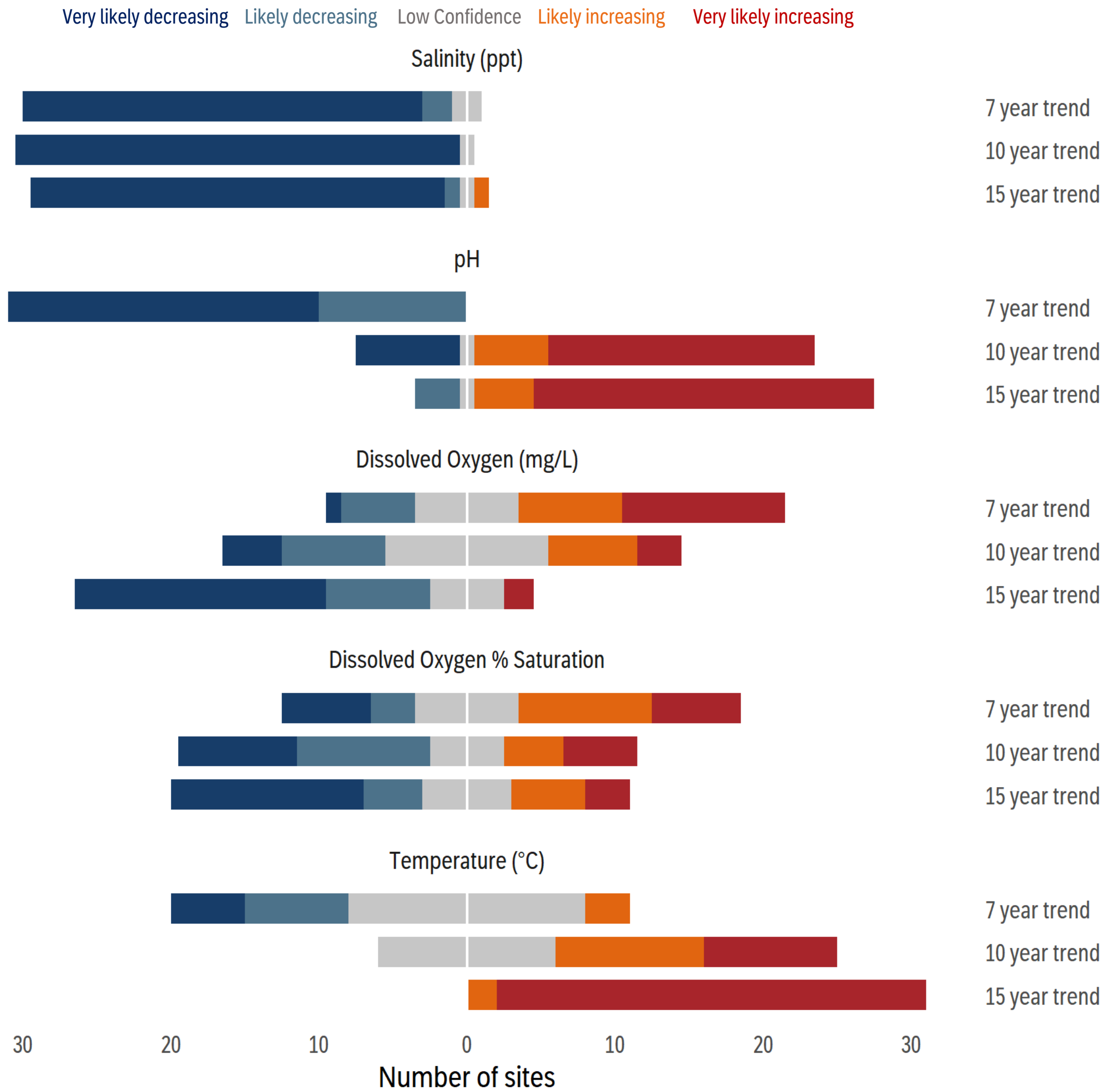

Figure 3-8. Comparison between trend periods in trend direction and confidence for field measured parameters across all sites monitored in the Auckland region.

4 East Coast

4.1 Background

The East Coast reporting area consists of three consolidated receiving environments (CRE) including North-East Coast, Mahurangi Harbour and Hibiscus Coast. The North East Coast extends from Te Arai Regional Park on the boundary with Northland region in the north to Sandspit in the south. This 242 km^2 area drains 1100 km of permanent streams that run eastward to beaches and estuaries along the Hauraki Gulf. The land cover in this CRE is predominantly rural, with approximately 57 per cent exotic grassland, 20 per cent indigenous forest and nine per cent exotic forest, seven per cent shrubland, five per cent urban and two per cent cropland (Figure 2-1). There were few changes in land cover since the last reporting period, most notably the conversion of some exotic grassland into shrubland and some conversion from exotic grassland and forest to urban areas. Goat Island/Rakiriri and Ti Point are the two monitoring sites closest to runoffs from this area but as open coastal sites are less likely to experience strong land use effects.

Mahurangi Harbour is a shallow drowned valley with a small surface area of 25 km^2 and a 128 km^2 catchment, draining eight permanent streams. The dominant catchment land cover is exotic grassland (54 per cent) followed by indigenous forest (20 per cent), exotic forest (9 per cent), shrubland (8 per cent) and urban area (7 per cent) mostly associated with the Warkworth settlement (Figure 2-1) (Auckland Council, 2025). Most notable land use changes were the construction of the Ara Tūhono – Pūhoi to Warkworth project on State Highway 1 which converted exotic forest and grassland to transport infrastructure along the western length of the harbour, and the growth of the Warkworth urban area (conversion from exotic grassland). Two estuarine monitoring sites are in the Mahurangi Harbour: Dawsons Creek and Mahurangi Heads. Dawsons Creek is more likely to indicate pressures due to land use as it is located in the upper to mid harbour, while Mahurangi Heads experiences higher dilution from marine waters in the Hauraki Gulf.

The Hibiscus Coast CRE comprises approximately 260 km^2 with 41 stream catchments. Land use is highly mixed with 32 per cent exotic grassland mainly in the hinterland and highly urbanised coastal areas (28 per cent of total area) with open space and reserves including the Long Bay Marine Reserve and Shakespeare Regional Parks. Indigenous forest makes up 16 per cent of the catchment, shrubland 13 per cent and exotic forest 10 per cent (Figure 2-1). Urban land cover in this area has grown by approximately two per cent since the last report, mostly converted from exotic grassland (Auckland Council, 2025). Other notable land use change was the conversion of approximate three per cent of the area from exotic grassland to indigenous shrubland at various locations, mostly in the backcountry. The open coast monitoring sites at Orewa and Browns Bay are most directly affected by run offs from the Hibiscus Coast area. These two sites are closest to urban areas but due to their exposed location they also experience high dilution from marine waters and the Hauraki Gulf.

4.2 State and Trend results

4.2.1 Physical parameters

At East Coast monitoring sites, median water temperatures were consistent among sites, ranging from 17.7°C to 18.0°C (Figure 4-1). The two estuarine sites in Mahurangi Harbour and the more southern open coastal sites at Orewa and Browns Bay exhibited broader temperature ranges, with minimum temperatures around 11°C to 13°C and maximums near 24°C. In contrast, Goat Island / Rakiriri and Ti Point showed narrower ranges, with a minimum of 14°C and a maximum of 23°C. Four sites showed decreasing trends in water temperature (Figure 4-2); these were very likely decreasing at both Mahurangi Harbour sites and Orewa and likely decreasing at Browns Bay. Conversely, Goat Island / Rakiriri displayed a likely increasing trend, whereas trend direction at Ti Point remained uncertain due to low confidence. These decreases in seven-year trends contrast with the 10-year trends which were likely to very likely increasing at all sites except Dawsons Creek (where confidence in trend direction was low). For the 15-year time period, water temperature trends were very likely increasing at all East Coast sites with magnitudes ranging from 0.03 to 0.07 °C per year.

Dawsons Creek in Mahurangi Harbour recorded lower median salinity and a wider range of values than the other East Coast sites (Figure 4.1). Median salinity at Mahurangi Heads was similar to that of the open coastal sites but with a slightly greater range observed. The open coast sites maintained median salinity values between 33 and 34 ppt, consistent with euhaline conditions. Salinity was very likely decreasing at all sites, though the rate of change was low, ranging from -0.1 to -0.2 ppt per year (Figure 4-2). Median pH values ranged from 8.0 at Dawsons Creek to 8.1 at Orewa and Ti Point. Trends in pH were either very likely or likely decreasing, though these changes were of low magnitude and likely reflect the observed decreases in salinity (Figure 4-2).

Dissolved oxygen concentrations (Figure 4-1) remained within guideline ranges, with saturation levels between 90 per cent and 110 per cent, and all readings were well above the 5 mg/L lower limit suggested for estuarine environments (Stevens et al., 2024). Dissolved oxygen saturation and concentration were likely or very likely increasing across most East Coast sites based on seven-year trends (Figure 4-2). However, 10- and 15-year trends showed likely or very likely decreases for both dissolved oxygen parameters across most sites.

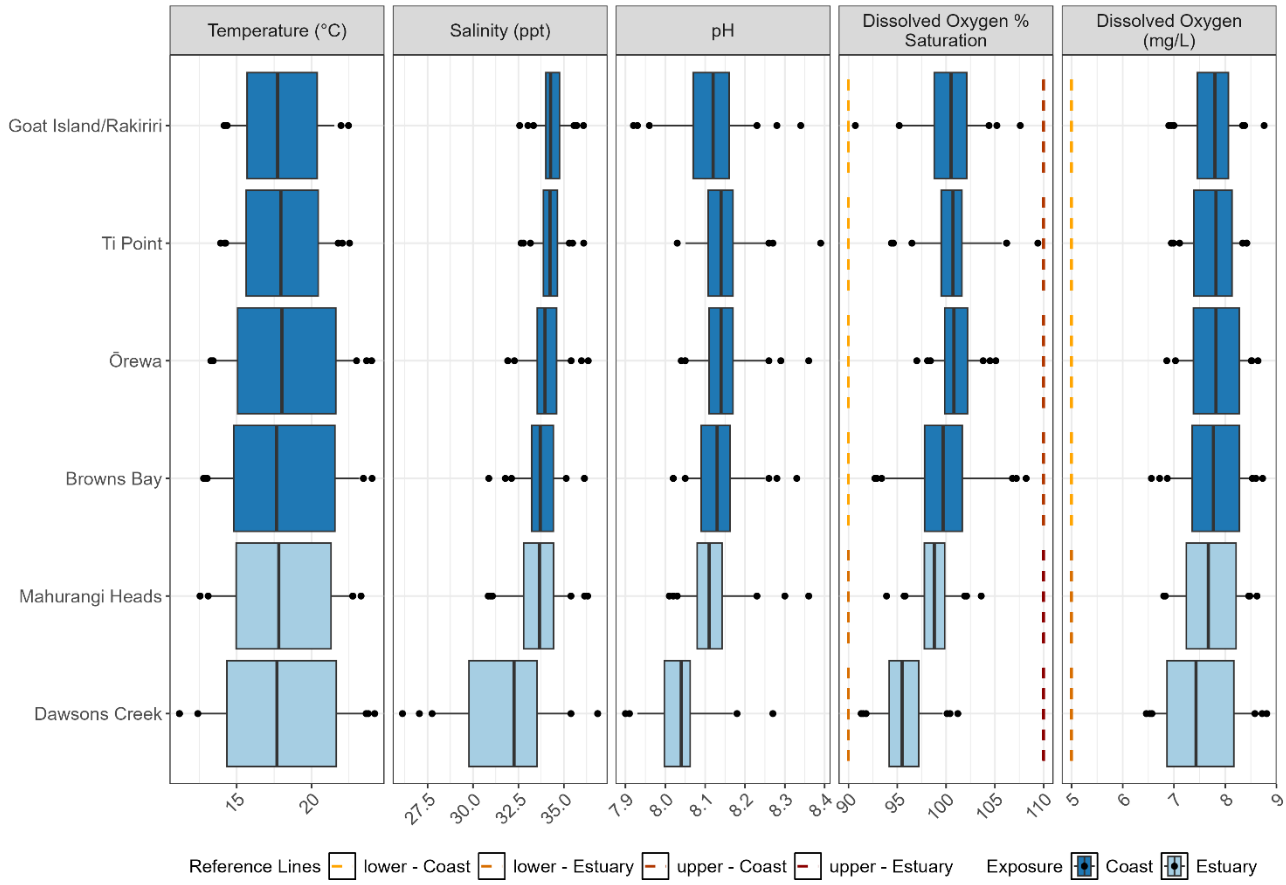

Figure 4-1. Boxplot for physical parameters at East Coast monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2.

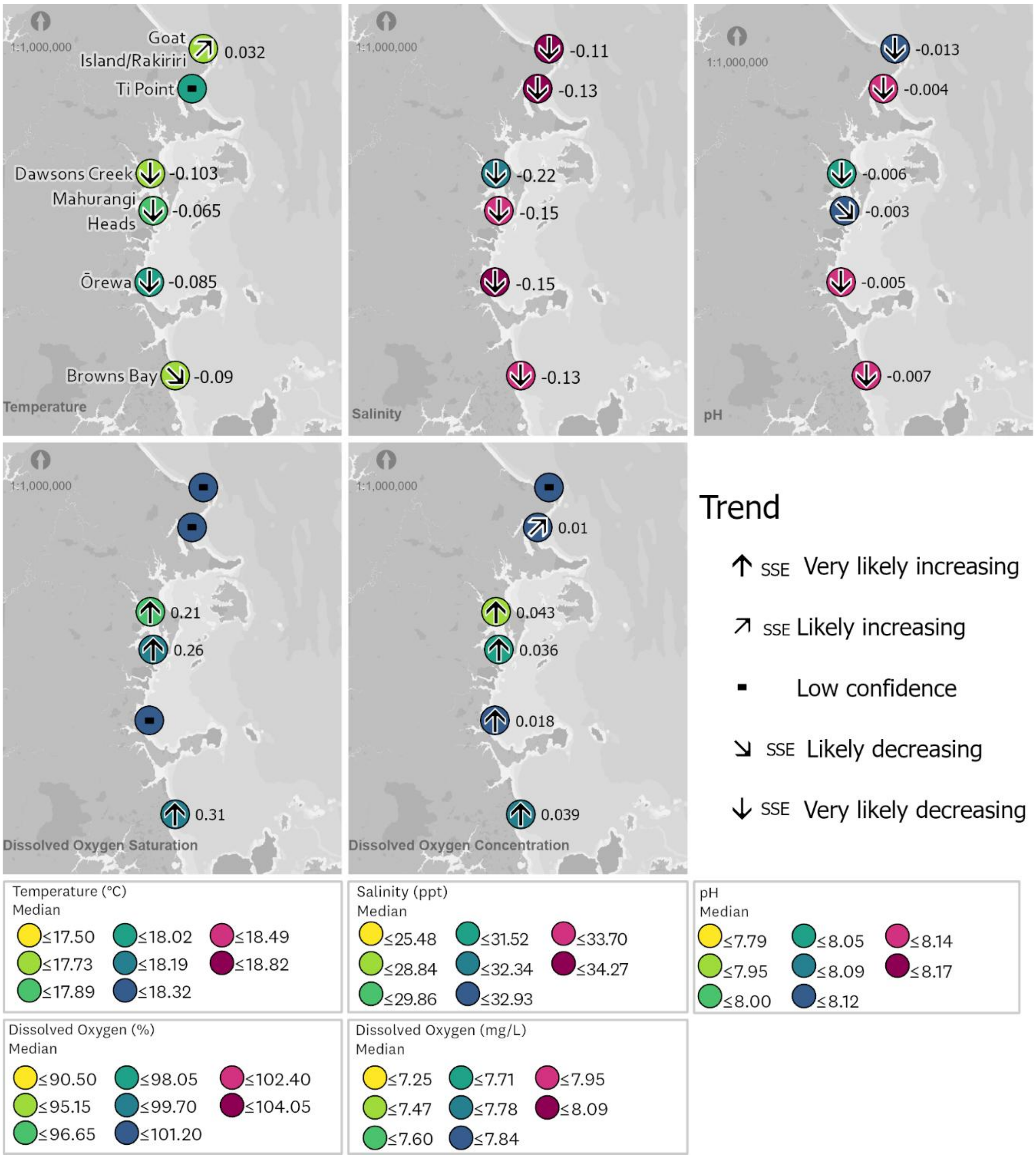

Figure 4-2. Maps showing state (2020 to 2024 median) and seven-year trend (2018 to 2024) information for physical parameters at East Coast monitoring sites. The Sen slope estimator (SSE) displays the annual Sen slope in the unit of the corresponding parameter.

4.2.2 Nutrients

At East Coast monitoring sites, five-yearly median concentrations for nutrient parameters remained below guidelines at all sites except for median total nitrogen concentrations at Ti Point which reached the guideline value for open coast sites of 0.12 mg/L (Figure 4-3). However, monthly statistics showed median guideline exceedances for nitrogen parameters at all East Coast sites except the two sites in the Mahurangi Harbour, and exceedances of the dissolved reactive phosphorus guideline in autumn and spring at Browns Bay (Appendix D, Figure D-1). All monthly exceedances were within 1.3 times the guideline value.

Median values for ammoniacal nitrogen were similar at all sites (approx. 0.012 mg/L) and seven-year trends were likely or very likely improving at low rates (average annual Sen slope of -0.0003 mg/L) (Figure 4-4). Total oxidised nitrogen concentrations showed differences between sites. Median values at Goat Island/Rakiriri and Ti Point were 0.0036 mg/L and 0.0074 mg/L, respectively and higher than other East Coast sites including the estuarine site Dawsons Creek (median 0.0021 mg/L). Trends for total oxidised nitrogen were heavily impacted by censored values due to the low concentrations at these sites and trend magnitude (annual Sen slopes) could not be determined. However, trend direction showed that trends were likely improving at most sites but at Ti Point and Goat Island/Rakiriri there were likely degrading and very likely degrading trends in total oxidised nitrogen. These sites also had degrading nitrate trends (Appendix C, Supplementary data).

Despite higher total oxidised nitrogen concentrations at Goat Island/Rakiriri compared to other sites, this site had the lowest total nitrogen concentrations (median 0.11 mg/L) across East Coast sites. The highest total nitrogen five-yearly median was observed at Dawsons Creek in Mahurangi (0.16 mg/L). Total nitrogen was very likely improving across all sites, though at low rates (Figure 4-4).

Dissolved reactive phosphorus concentrations ranged from median values of 0.006 mg/L at Ti Point to 0.012 mg/L at Browns Bay and median concentrations at all sites were below the relevant guidelines (Figure 4-3). However, at Browns Bay, dissolved reactive phosphorus concentrations exceeded the guideline value from March to August (based on monthly medians across the five years, Appendix D, Figure D-1). Similarly, total phosphorus concentrations were highest at Browns Bay (median 0.017 mg/L) and lowest at Goat Island/Rakiriri (median 0.009 mg/L) and remained below the guideline value almost all the time. Dissolved reactive phosphorus was very likely improving across all sites (average annual Sen slope: -0.004mg/L). Total phosphorus trends were not analysed due to changes in lab methods (see Section 2).

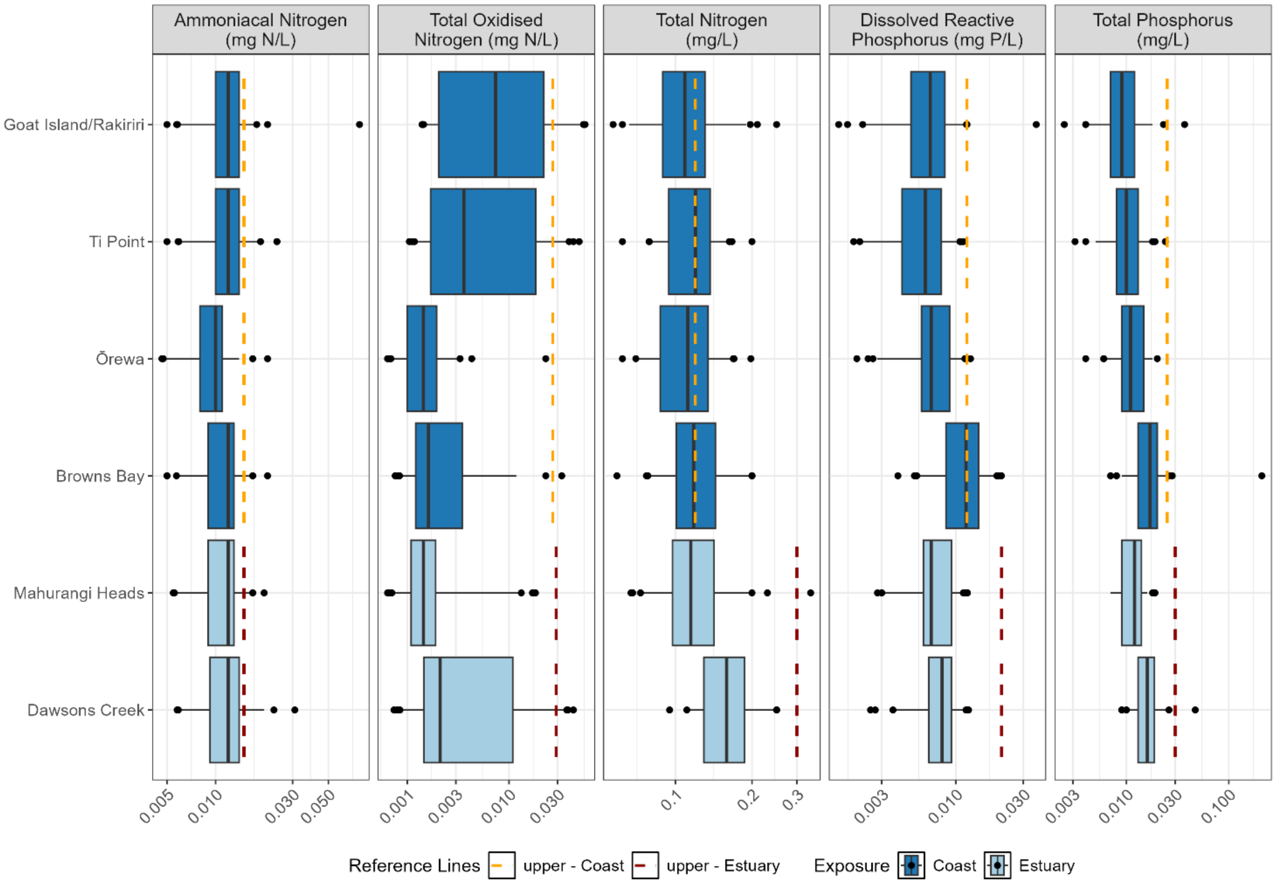

Figure 4-3. Boxplots showing nutrient parameters at East Coast monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2. The x-axis is shown at log scale.

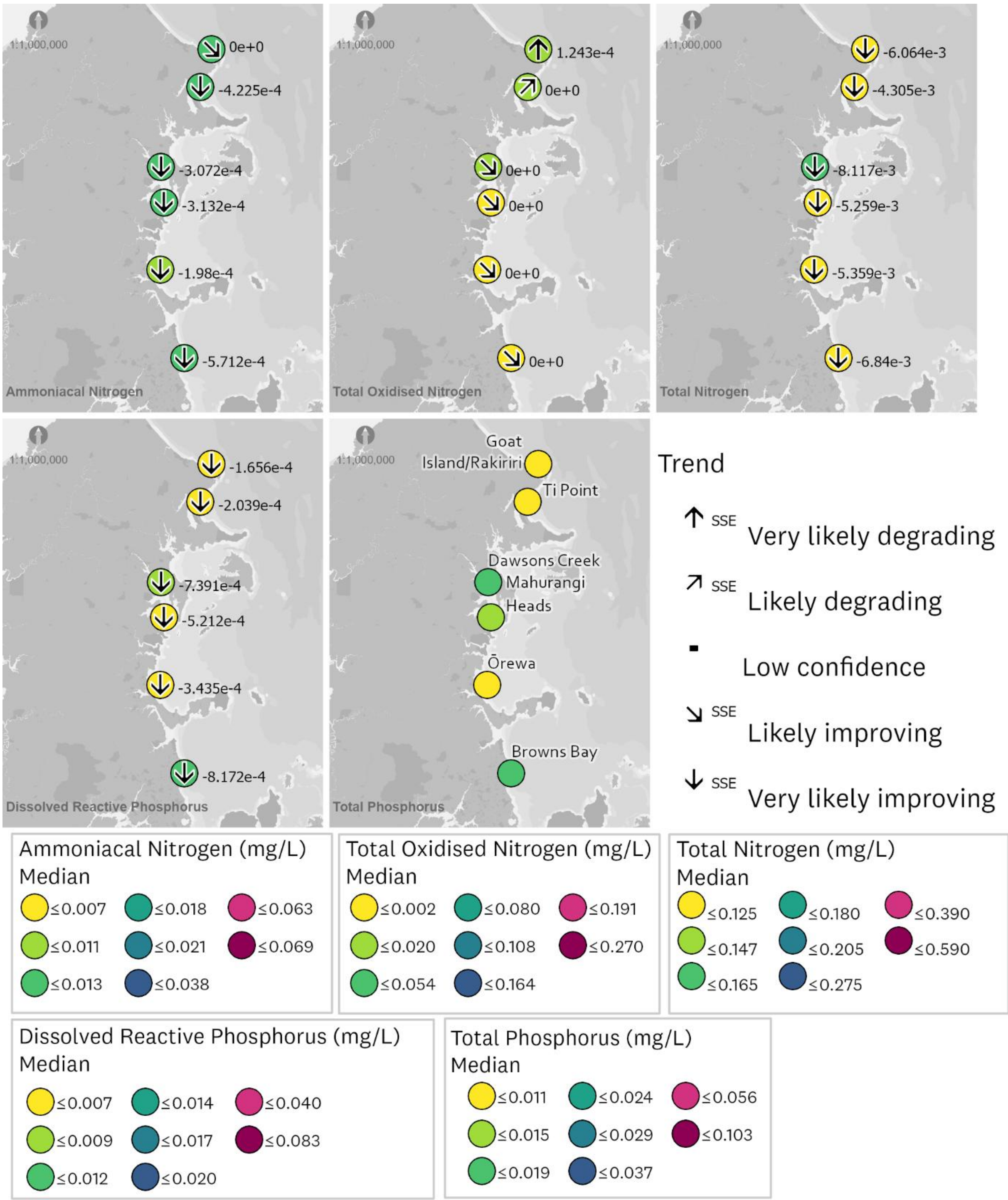

Figure 4-4. Maps showing state (2020 to 2024 median) and seven-year trend (2018 to 2024) information for nutrient parameters at East Coast monitoring sites. The Sen slope estimator (SSE) displays the annual Sen slope in the unit of the corresponding parameter.

4.2.3 Water clarity

Water clarity parameters had lower concentrations at the open coast sites compared to the two estuarine sites, Mahurangi Heads and Dawsons Creek (Figures 4-5 and 4-6). Among all sites, Dawsons Creek recorded the highest concentrations of chlorophyll *a*, turbidity, and total suspended solids. Chlorophyll *a* concentrations remained below guideline thresholds for both the 90th percentile and the median[3] at all sites during the current reporting period. Seven-year trend analyses indicated improving chlorophyll *a* levels across all East Coast sites, with very likely improving trends at Browns Bay and Dawsons Creek and likely improving trends at all other sites (Figure 4-6). Censored values affected trend analysis at Orewa and Ti Point and annual Sen slopes could not be estimated at these two sites.

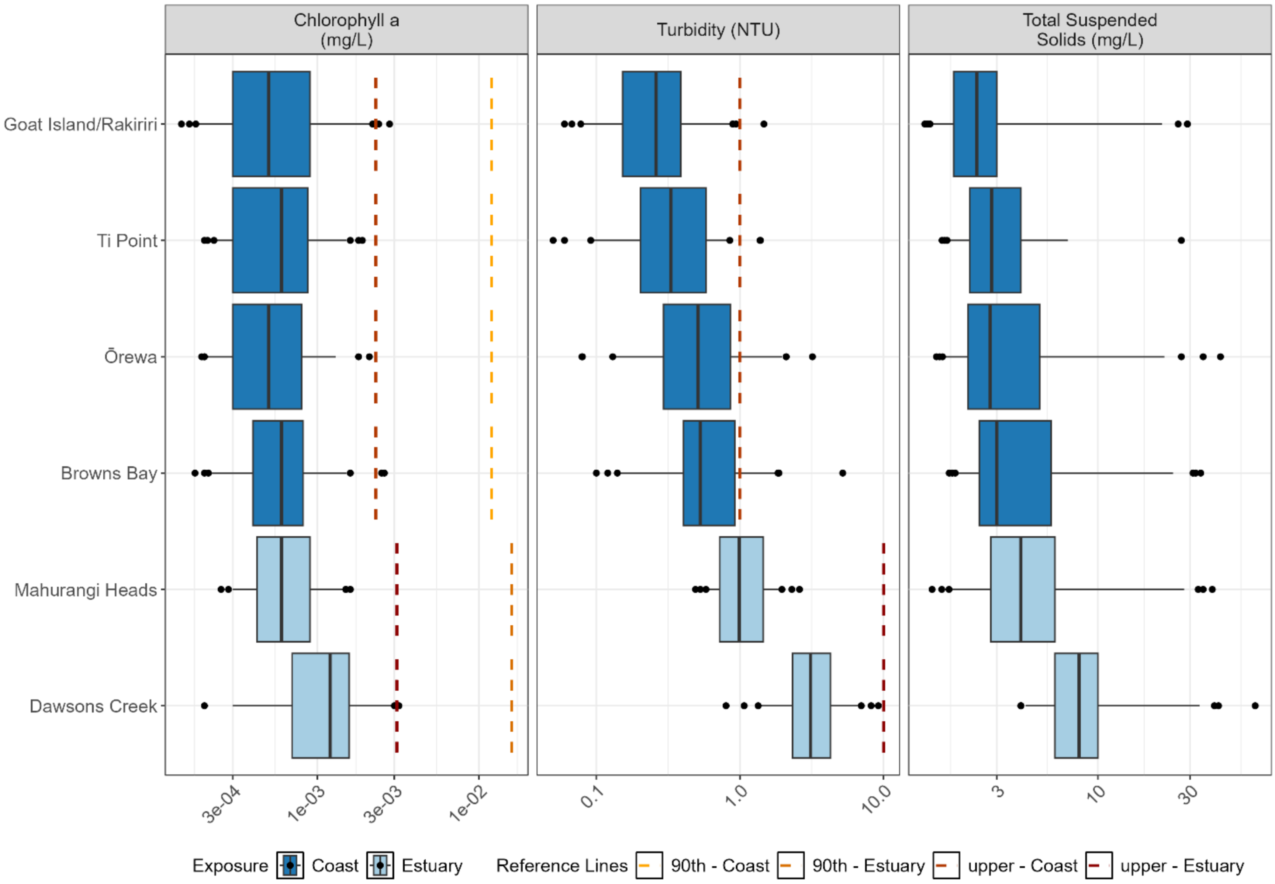

Figure 4-5. Boxplots showing water clarity parameters at East Coast monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2. The x-axis is shown at log scale.

Turbidity remained consistently below 10 NTU at all East Coast sites during the current reporting period. Median turbidity levels at the coastal sites were typically below 1 NTU, with only occasional outliers or higher percentile values exceeding this guideline. two sites monthly statistics revealed median exceedances of the 1 NTU guideline value, in March and June at Browns Bay and November at Orewa, respectively (Appendix D Figure D-2). Trend analysis indicated improvement, revealing very likely improving turbidity trends across all sites (Figure 4-6). The magnitude of these trends ranged from a minor 0.02 NTU annual reduction at Goat Island/Rakiriri to a 0.27 NTU annual reduction at Dawsons Creek.

[3] Chlorophyll *a* is highly seasonal with peak concentrations often occurring during warmer months only. Comparison to guidelines based on the median and 90th percentile provides information of elevated concentration under general conditions throughout the year and during seasonal phytoplankton bloom, respectively.

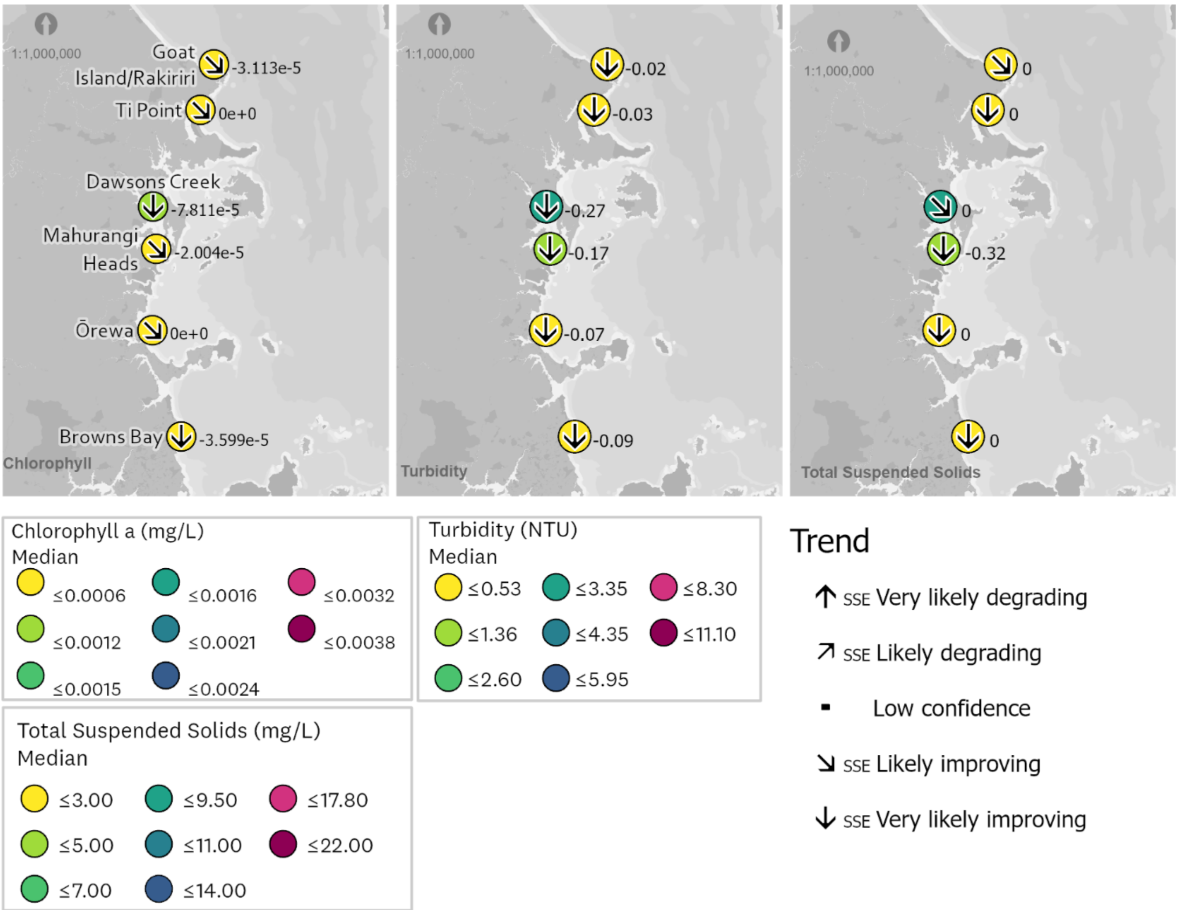

Figure 4-6. Maps showing state (2020 to 2024 median) and seven-year trend (2018 to 2024) information for water clarity parameters at East Coast monitoring sites.

During the 2020 to 2024 reporting period, median total suspended solids concentrations stayed below 10 mg/L (Figures 4-5 and 4-6). However, isolated outliers reached as high as 40 mg/L, indicating occasional increases. Seven-year trend analysis identified likely to very likely improving trends in total suspended solids at all sites (Figure 4-6). However, due to a high proportion of censored and tied values, trend magnitudes could not be reliably calculated for most sites except for Mahurangi Heads. At this site, the estimated trend showed an annual decrease of 0.3 mg/L.

4.3 Discussion

At the East Coast monitoring sites, data ranges for water temperature, salinity and pH were comparable to previous reporting (Ingley and Groom 2022, Kelly and Kamke 2023). State statistics confirmed predominantly euhaline (>= 30 ppt) conditions at open coastal sites and polyhaline (18-30 ppt) conditions at the two estuarine sites in the Mahurangi Harbour. Decreasing trends in salinity were likely influenced by wet weather events in the reporting period (Section 3). Declining trends in pH were likely equally driven by wet weather as increased freshwater volumes lower the pH.

All sites except the northernmost sites (Goat Island/Rakiriri and Ti Point) experienced decreasing temperature trends. Previous reporting identified increasing temperatures at East Coast sites (Ingley 2020) and 10- and 15-year trends similarly found increases in water temperature for all East Coast sites. Short-term trend periods such as seven-years are more likely to be influenced seasonally or by events such as the rain events in 2023. Long-term trends are more likely to produce robust trend results. Increases in water temperature over the longer period are consistent with national reporting for coastal waters (Fraser et al., 2021, Shears et al., 2024).

Encouragingly, at the East Coast sites there were few signs indicating nutrient enrichment. Only one guideline was exceeded at one site for the five-yearly median values (total nitrogen at Ti Point). Some exceedances were recorded for monthly median values, which were of low magnitude. For nitrogen parameters, these were mainly for total oxidised nitrogen and ammoniacal nitrogen at Goat Island/Rakiriri and Ti Point. Previous reporting also showed higher total oxidised nitrogen concentrations at these two sites compared to other East Coast sites (Kelly and Kamke, 2023), consistent with the findings in this report. Neither site is located close to a direct freshwater source but it is possible that run off from the catchment has high nitrate concentrations; however, the contribution of other sources including oceanic ones cannot be excluded. Nitrogen parameters are highly dynamic in coastal waters and biologically available form of nitrogen such as total oxidised nitrogen can be rapidly assimilated by microalgae and bacteria and transformed into organic forms of nitrogen. Because of possible rapid transition of nitrogen species total nitrogen is considered the more stable indicator for eutrophication in coastal waters (Stevens et al., 2024). It is important to consider nitrogen parameters together with other indicators of eutrophication such as chlorophyll *a* and dissolved oxygen. At other East Coast sites total oxidised nitrogen may have been assimilated at a faster rate resulting in comparatively higher concentrations at Goat Island and Ti Point. Despite the higher total oxidised nitrogen concentrations at these two sites, there were few signs of eutrophication based on our results for total nitrogen, chlorophyll *a* and dissolved oxygen (see below).

For phosphorus parameters, exceedances of monthly median values for dissolved reactive phosphorus were recorded over autumn and winter at Browns Bay. This was observed previously and was interpreted as an effect of seasonal nutrient cycling in the Hauraki Gulf (Ingley and Groom 2022) where lower consumption of phosphorus by primary producers over winter was observed leading to increased phosphorus concentrations inshore at the inner gulf (Zeldis et al., 2013). Overall, exceedances of the guidelines were few and at low magnitudes. Nutrient trends for all parameters were improving across all sites.

Secondary indicators of nutrient enrichment such as chlorophyll *a* (a proxy for algal growth) and dissolved oxygen concentrations were well below or within guideline values, respectively. Minimum dissolved oxygen concentration for the 2024 reporting period ranged from 6.5 to 7.0 mg/L which corresponds to good grading if compared to the proposed minimum dissolved oxygen indicator for estuaries (Stevens et al, 2024). That indicator is based on a seven-day mean minimum for continuous monitoring data. While the statistics presented in this report are based on monthly discrete monitoring data, application of the indicator to such data was suggested in the report as a “conservative limit that if breached in discrete sampling raises the need for intense investigation” (Stevens et al, 2024). Trends for dissolved oxygen for the seven-year period were increasing and chlorophyll *a* trends were decreasing indicating that despite occasional nutrient exceedances our monitoring did not pick up any signs of nutrient enrichment at East Coast sites.

For the water clarity parameters, turbidity and total suspended solids, analyses revealed low concentrations, particularly at open coast sites. Estuarine sites had slightly higher primary productivity as indicated by chlorophyll *a* and at times higher turbidity and total suspended solids concentrations but still at levels indicating low primary productivity and clear waters. Trends were very likely or likely improving for all three parameters at slow rates, confirming low impacts on water clarity at East Coast sites.

Overall, our reporting showed improvements in water quality at East Coast monitoring sites compared to previous reporting (Ingley 2021; Kelly and Kamke 2023). This was especially so in the Mahurangi Harbour where no guideline exceedances were recorded in the current reporting period. It should be noted that our monitoring programme is not designed to detect signs of (reported) wastewater overflow discharges into the Mahurangi Harbour. The sample timing, frequency, and monitoring parameters of our state of the environment monitoring are not suitable for making the required targeted connections.

5 Waitematā Harbour

5.1 Background

5.1.1 Sites and land cover

The Waitematā Harbour catchment includes an area of approximately 450 km^2 with 59 streams draining into the Waitematā Harbour. The harbour is classified as a shallow drowned valley (Hume et al., 2016) and has an area of 80 km^2. The main land cover class in the catchment is urban (51 per cent), followed by exotic grassland, indigenous and exotic forest (Figure 2-1). Land cover in the catchment is distinctly different between the northern sub-catchments draining into the upper harbour and the southern sub-catchments feeding into the central harbour. Land cover classes in the northern catchment include mainly exotic grassland, forestry mainly at Riverhead, and some horticultural land use mostly in the northwestern part of the catchment. The central harbour catchment is dominated by urban land cover. Conversion of exotic grassland to urban land cover over the time period from 2018 to 2024 was notable in the northwestern part of the catchment. There were also large areas of forest harvesting at Riverhead, resulting in conversion to exotic grassland, and conversely some conversion of exotic grassland to indigenous and exotic forest and shrubland (Auckland Council, 2025).

5.2 State and Trend Results

5.2.1 Physical parameters

Water temperatures was largely consistent between sites in the Waitematā Harbour with median temperatures around 18°C, minima around 10°C and maxima around 24°C (Figures 5-1 and 5-2). Temperatures were likely decreasing at most sites (Figure 5-2). When the trends were assessed over 15 years, temperatures were very likely increasing across all sites. Salinity was very likely decreasing at all sites except at Brighams Creek where it was likely decreasing (Figure 5-3). Similarly, pH was very likely decreasing (likely decreasing at Chelsea) across the Waitematā Harbour. Drops in salinity and pH were observed during summer and autumn 2023 when storm events in the Auckland region delivered increased rainfall and river flows. Both salinity and pH statistics followed typical spatial patterns as described previously (Kamke 2025, Ingley and Groom 2022) with more variability at the upper harbour tidal creek sites and a narrower range at the central harbour estuarine sites.

For five-yearly state statistics, dissolved oxygen saturation and concentrations remained within guidelines (Figure 5-1) and the minimum threshold of 5 mg/L (Stevens et al., 2024). Trends for dissolved oxygen saturation and concentration showed a varied picture across sites (Figure 5-2). Most tidal creek sites showed decreasing trends except Rangitōpuni Creek, where there were likely increasing trends. At Chelsea, the outermost harbour site, there were very likely increasing trends in both dissolved oxygen parameters. At Whau Creek trends in both dissolved oxygen measures were likely or very likely decreasing, as were the dissolved oxygen saturation trends at Henderson and Hobsonville. At the latter two sites, trends in dissolved oxygen concentration were either of low confidence (Hobsonville) or conflicting with the dissolved oxygen saturation trend showing likely increasing concentrations (Henderson).

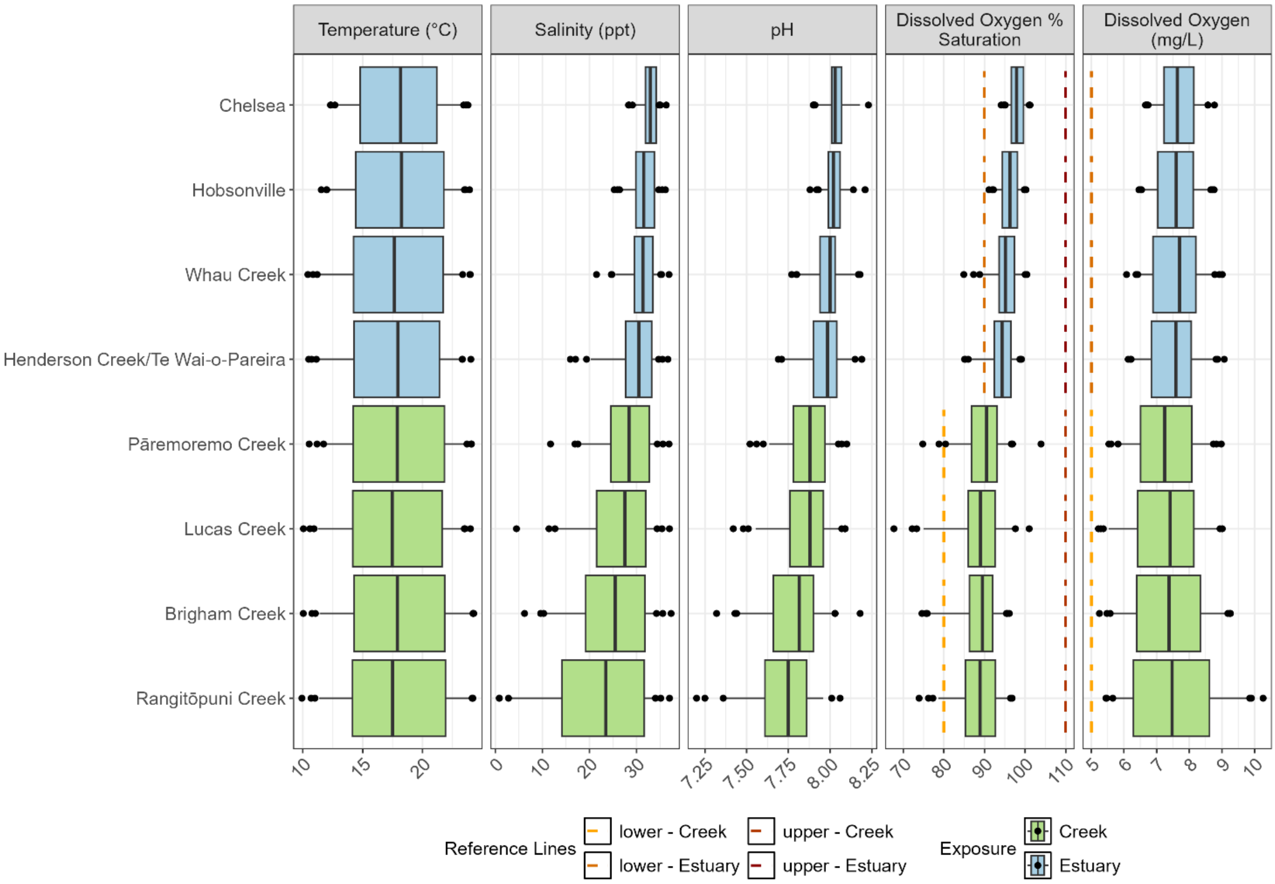

Figure 5-1. Boxplots showing physical parameters at Waitematā Harbour monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2.

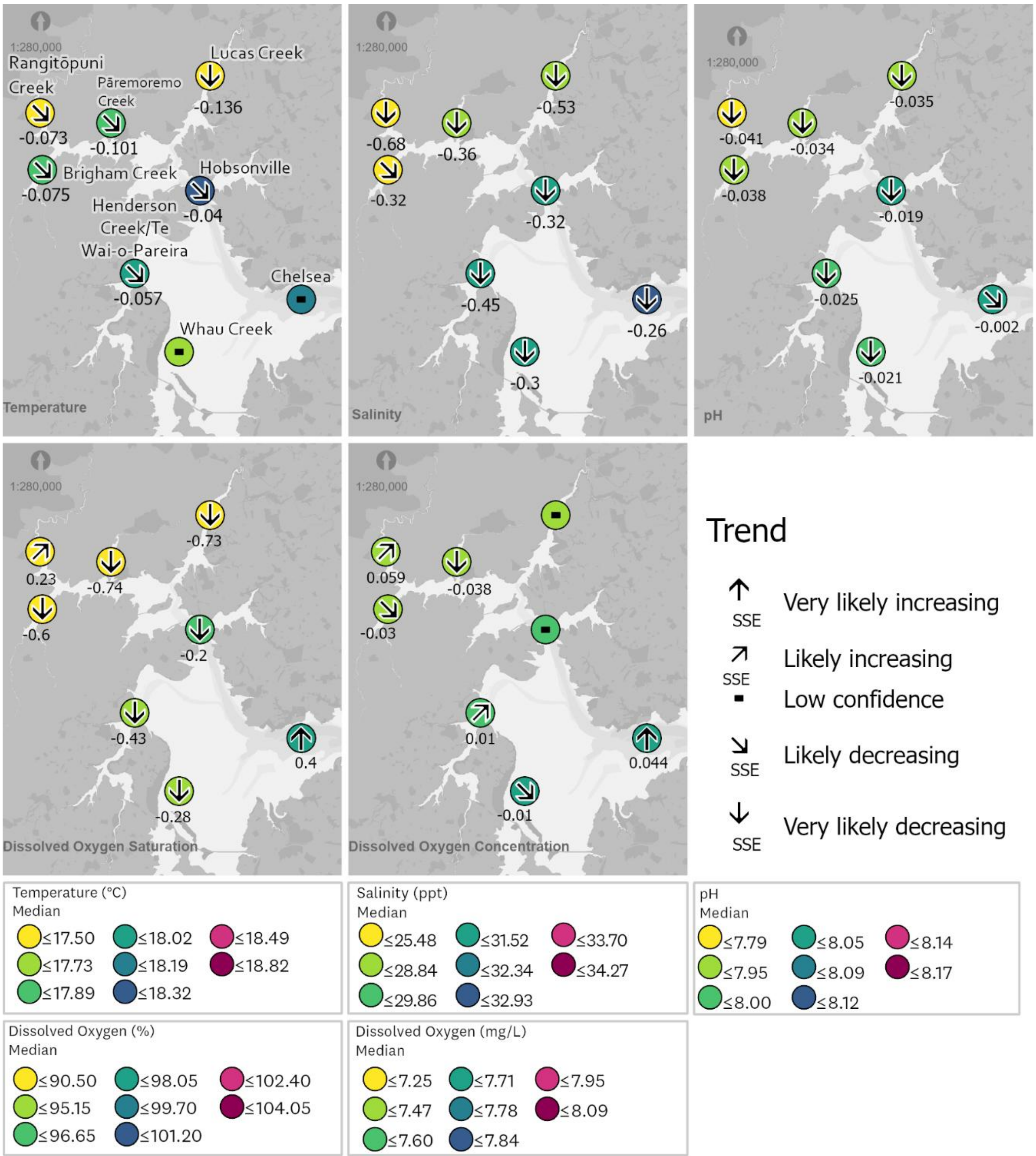

Figure 5-2. Maps showing state (2020 to 2024 median) and seven-year trend (2018 to 2024) information for physical parameters at Waitematā Harbour monitoring sites. The Sen slope estimator (SSE) displays the annual Sen slope in the unit of the corresponding parameter.

5.2.2 Nutrients

Nutrient concentrations follow a similar spatial gradient to salinity in the Waitematā Harbour. The highest nutrient concentrations and largest data ranges were found at the upper harbour tidal creek sites and the lowest concentrations at Chelsea, the outermost central harbour site (Figures 5-3 and 5-4). At sites in the mid central harbour (Hobsonville, Whau Creek and Henderson Creek) median nutrient concentrations ranged between those of Chelsea and the upper harbour creek sites, with median ammoniacal nitrogen and total oxidised nitrogen concentrations at Henderson Creek exceeding those of Pāremoremo Creek and Lucas Creek (Figures 5-3 and 5-4). At Whau Creek, Henderson, and Hobsonville, peak nitrogen and phosphorus concentrations were recorded in May 2023, coinciding with a drop in salinity indicating strong rainfall. At the upper harbour sites, some elevated nutrient concentrations were also detected during summer 2022/23 and autumn 2023, but these were less pronounced than those May peaks at the central harbour sites. Five-yearly state statistics showed that nutrient concentrations (median and upper percentiles) at Rangitōpuni Creek and Brighams Creek were highest in the harbour for all parameters with some guideline exceedances. Five-yearly median ammoniacal nitrogen and total nitrogen concentrations exceeded the guideline value at these sites. At Rangitōpuni Creek, there were substantial differences in median total oxidised nitrogen concentrations between summer/autumn (November to April) when concentrations were lower; and in winter/spring (June to October) when concentrations were higher. In winter/spring, monthly median values consistently exceeded the guideline value (Appendix D, Figure D-3). A similar pattern was observed at Brighams Creek with median concentrations exceeding the guideline value in winter months (Appendix D, Figure D-3).

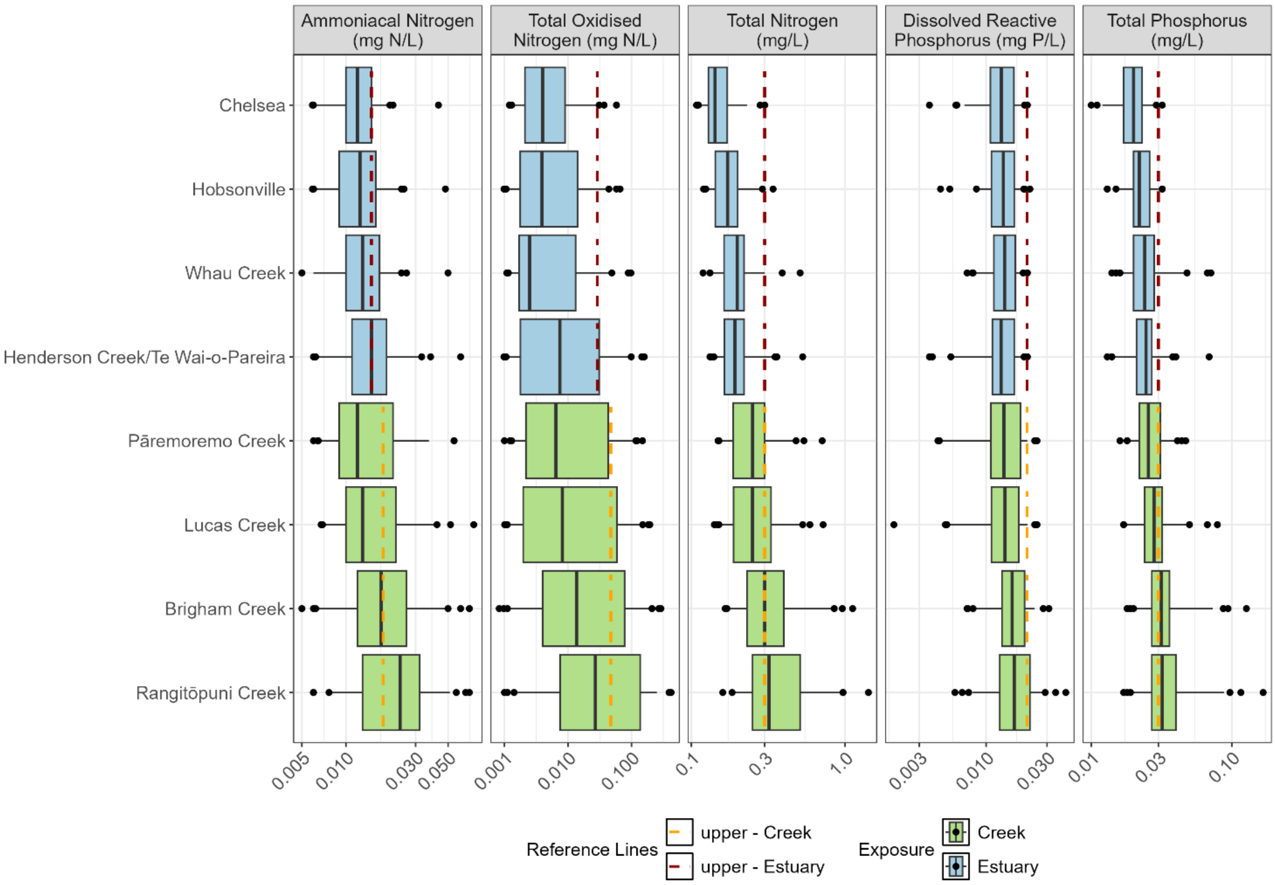

Figure 5-3. Boxplots showing nutrient parameters at Waitematā Harbour monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2. The x-axis is shown at log scale.

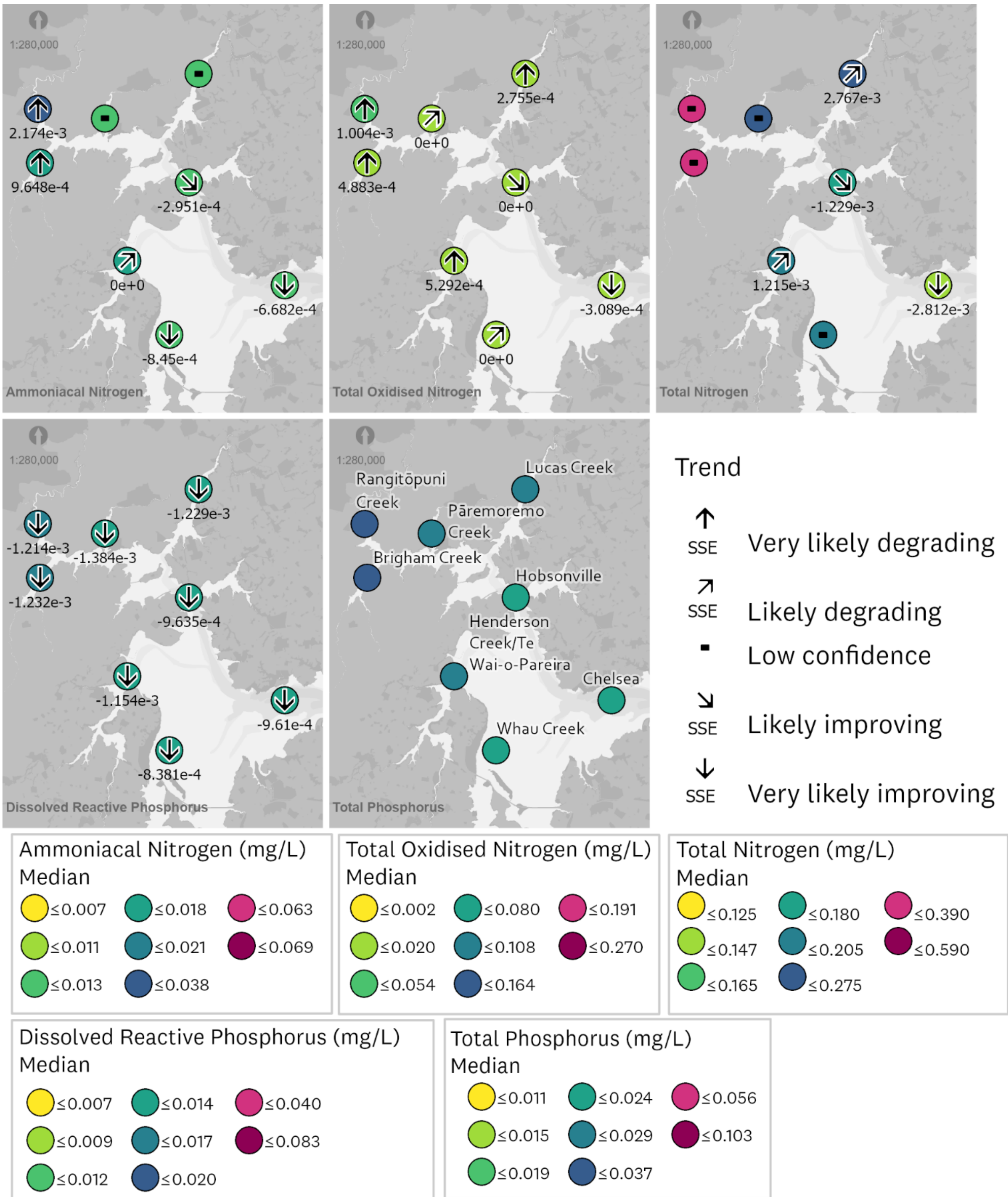

Figure 5-4. Maps showing state (2020 to 2024 median) and seven-year trend (2018 to 2024) information for nutrient parameters at Waitematā Harbour monitoring sites. The Sen slope estimator (SSE) displays the annual Sen slope in the unit of the corresponding parameter.

Trend results for nitrogen parameters were variable between sites in the Waitematā Harbour. At Chelsea and Hobsonville trends for all nitrogen parameters were very likely and likely improving but at low magnitudes (Figure 5-4). The data resolution at for total oxidised nitrogen at Hobsonville was too low to determine the trend magnitude. At Whau Creek trends for ammoniacal nitrogen were very likely improving, but total oxidised nitrogen was likely degrading and there was low confidence in the trend direction for total nitrogen (Figure 5-4). At Henderson Creek and all upper harbour tidal creek sites no improving trends for nitrogen parameters were detected. Trend directions varied between very likely degrading, likely degrading and low confidence (Figure 5-4). At Rangitōpuni Creek trend magnitudes for ammoniacal nitrogen (annual Sen slope: 0.002 mg/L) and total oxidised nitrogen (0.00 1 mg/L) were noticeably higher than at other sites in the Waitematā Harbour indicating relatively fast degradation.

Trends for dissolved reactive phosphorus were very likely improving at all sites in the Waitematā Harbour (Figure 5-4). Trend magnitudes ranged from -0.0014 mg/L at Pāremoremo Creek to -0.0008 mg/L at Whau Creek.

5.2.3 Water clarity

Median chlorophyll *a* concentrations were highest at upper harbour creek sites, though slightly lower at the Pāremoremo Creek site (Figures 5-5 and 5-6). The central harbour sites Hobsonville, Whau Creek, and Henderson had lower median chlorophyll *a* concentrations than upper harbour creek sites, but similar peaks in 95th percentiles. None of the five-year median concentrations exceeded guidelines for chlorophyll *a* but the 75th percentiles at most sites exceeded the creek guideline, indicating a potential for seasonal exceedances (Figure 5-5). The monthly statistics showed those seasonal exceedances of the upper guideline for the medians at Brigham Creek, Rangitōpuni Creek and Pāremoremo Creek (Appendix D, Figure D-4). There was low confidence in trends for chlorophyll *a* at the tidal creek sites except for Lucas Creek where there were very likely degrading trends (annual Sen slope: 0.0001 mg/L). Chlorophyll *a* trends were also likely or very likely degrading at the central harbour sites with the highest magnitude increases measured at Whau Creek and Chelsea (Figure 5-6).

Median turbidity values ranged from 2.4 NTU at Chelsea to 7.3 NTU at Brighams Creek. The upper harbour creek sites were generally more turbid than the central harbour sites (Figure 5-6) but did not exceed guideline values. At Lucas Creek, monthly medians exceeded the guideline slightly (1.1- to 1.4-fold) from September to December (Appendix D, Figure D-4). There was low confidence in the direction of trends in turbidity at Lucas Creek. At all other tidal creek sites and at Chelsea turbidity trends were very likely or likely improving (Figure 5-6). The turbidity trend at Whau Creek was very likely degrading (Figure 5-6). This site showed elevated turbidity (and total suspended solids) in November 2022, February 2023, and May 2023 during intense wet weather events (see Section 3) that may have influenced this trend result.

Total suspended solids concentrations did not exhibit the same spatial gradient as the other water clarity parameters of higher concentrations in the upper harbour, and lower concentrations in the central harbour (Figures 5-5 and 5-6). The highest concentration was at Lucas Creek (median: 16 mg/L) and the lowest at Chelsea (median: 7 mg/L). However, median values at the other sites had similar concentrations to each other (between 10 mg/L and 14 mg/L) (Figure 5-6). The upper percentile concentrations were higher at Whau Creek, Henderson and Hobsonville than most tidal creek sites (Figure 5-5). Consistent with the findings for turbidity, these three mid-harbour sites experienced peak concentrations in total suspended solids during 2023 storm events. These peaks were highest at Whau Creek. At these three sites, there were likely or very likely degrading trends in total suspended solids concentrations, with annual Sen slope ranging from 0.25 mg/L at Henderson to 0.8 mg/L at Whau Creek (Figure 5-6). At the remaining sites, trends were very likely improving (3 sites) or there was low confidence (2 sites) in the trend direction (Figure 5-6). Of the three sites with improving trends, Rangitōpuni Creek and Brighams Creek showed the highest trend magnitude with annual Sen slopes of -1.25 mg/L and -0.68 mg/L respectively (Figure 5-6).

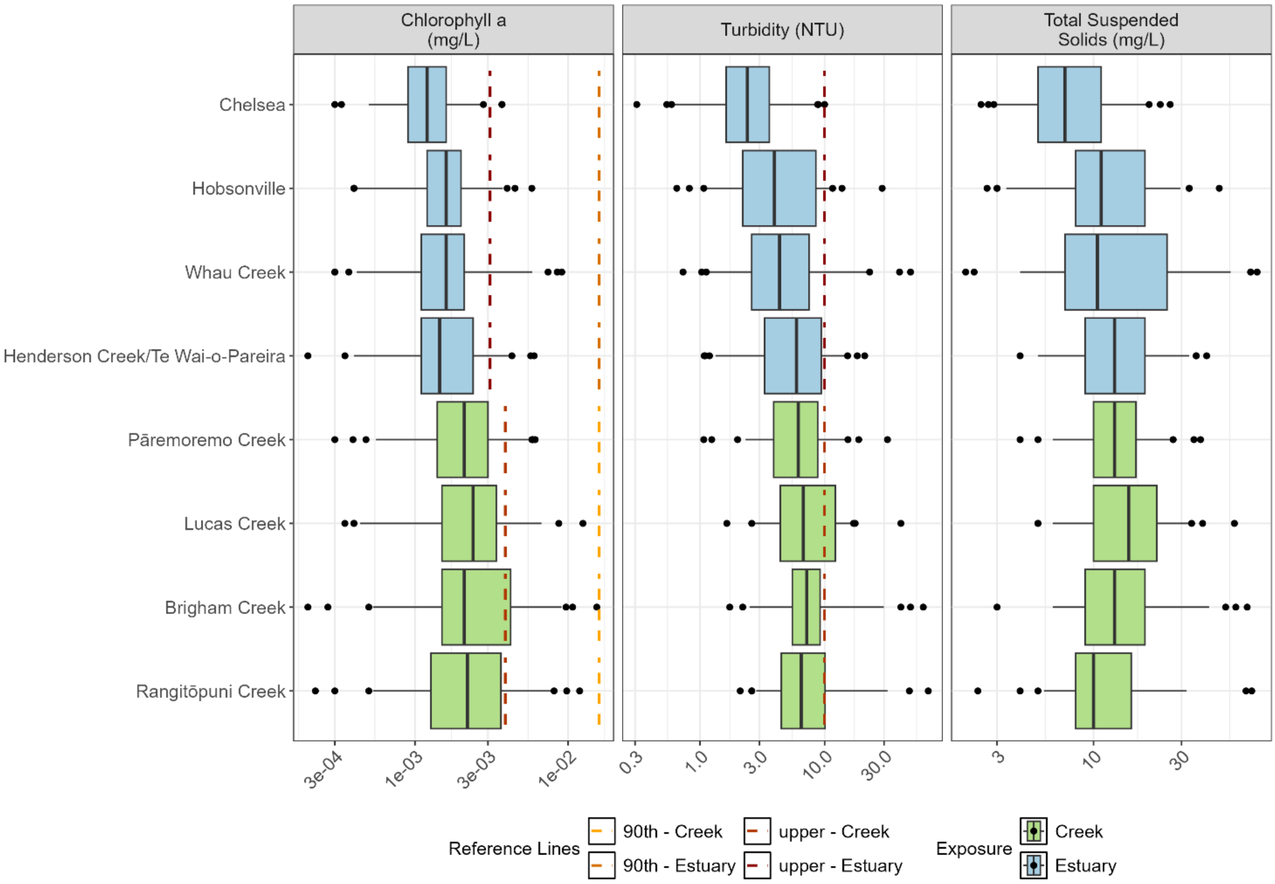

Figure 5-5. Boxplots showing water clarity parameters at Waitematā Harbour monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2. The x-axis is shown at log scale.

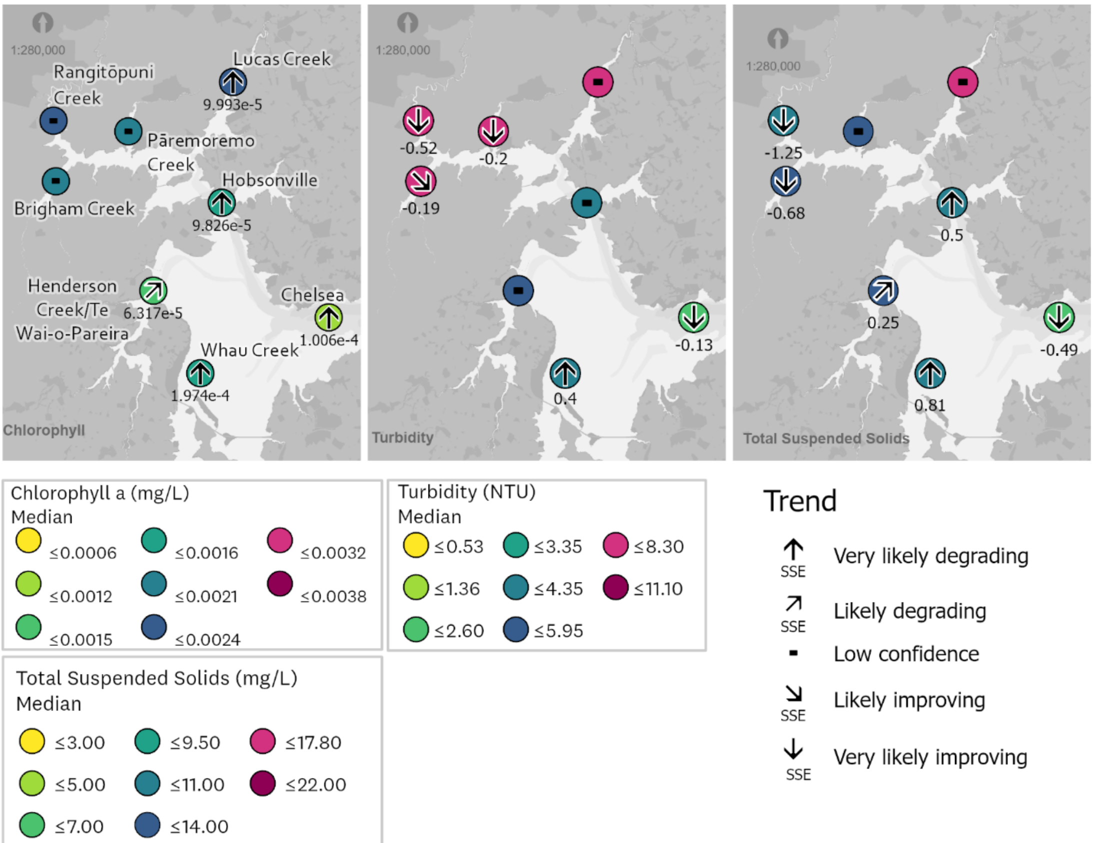

Figure 5-6. Maps showing state (2020 to 2024 median) and 7-year trend (2018 to 2024) information for water clarity parameters at Waitematā Harbour monitoring sites. The Sen slope estimator (SSE) displays the annual Sen slope in the unit of the corresponding parameter.

5.3 Discussion

In the Waitematā Harbour, salinity and pH followed a clear spatial pattern of wider data ranges at the upper harbour tidal creek sites with lower minima and greater maxima than observed at central harbour sites. The freshwater influence at these upper harbour creek sites is highest, as observed in the lowest salinity values. More saline water is brought into the tidal creeks with increasing tidal height, influencing salinity and pH. While our monitoring is standardised to mid-ebb tide (outgoing), the difference in tidal height and freshwater flows throughout the year create the observed data variability. This pattern has been reported previously (Ingley and Groom, 2022). Water temperature ranges were comparable between the upper tidal creek sites and the mid harbour sites Hobsonville, Whau Creek and Henderson. The outermost harbour monitoring site (Chelsea) experienced a slightly narrower temperature range than other sites due to lower freshwater influence at this site. Water temperature trends indicated decreasing temperatures over the seven-year trend period but over a 15-year period the trend direction changed to increasing. It is likely that increased rainfall towards the end of the seven-year trend period caused a drop in temperature that impacted the trend direction more strongly in the short trend period. The trend direction of the longer trend period likely reflects increasing coastal water temperature which was also observed nationally (Fraser et al., 2021, Shears et al., 2024).

As shown in Section 3 for the regional overview, seven-year trends in salinity and pH in the Waitematā Harbour were also influenced by wet weather events throughout the trend period. While salinity trends were very likely decreasing for all trend periods, the magnitude of the trend in the seven-year periods was stronger (average annual Sen slope -0.4 ppt) than in the 15-year trend period (average annual Sen slope -0.15 ppt) thus showing the greater effect of wet weather events on the shorter trend period. For pH, seven-year trends were mostly decreasing due to the high freshwater inputs during the latter years of this period but in the 15-year trend period pH trends were increasing at many Waitematā Harbour sites. Rangitōpuni Creek was the exception to this where 15-year trends also showed likely decreasing trends at low annual rates of change. Rangitōpuni Creek shows some signs of nutrient enrichment with total oxidised nitrogen exceeding guidelines at times. Increasing nutrient pressure can accelerate the decrease of pH as shown for the Hauraki Gulf (e.g. Law et al., 2017, Zeldis et al., 2022). Whether there is connection between decreasing pH and increased metabolism due to nutrient enrichment at this site would need to be investigated.

Signs of nutrient pressures were observed in the upper Waitematā Harbour tidal creek sites and at Henderson in the mid harbour. Nutrient guideline exceedances were frequent at these sites, and most frequent at Rangitōpuni Creek and Brighams Creek. This included all nitrogen parameters and most prominently total oxidised nitrogen in winter and early spring. Chlorophyll *a* guideline exceedances were also observed at these sites, mostly in late spring and summer when water temperatures increased. A typical pattern of dynamics between temperature, chlorophyll *a* and total oxidised nitrogen was observed. When temperatures warmed, phytoplankton growth caused chlorophyll *a* concentrations to increase. The increase in phytoplankton biomass led to increased uptake of total oxidised nitrogen, resulting in reduced seawater concentrations of this nutrient. These dynamics chlorophyll *a* were documented previously for sites in the Waitematā Harbour (Kelly and Kamke, 2023). This is a naturally-occurring process but in the case of high nutrient availability algae can bloom and become a nuisance.

When in bloom, algae can produce high amounts of organic matter which is consumed by microorganisms when it sinks in the water column. The consumption of this organic matter requires oxygen as does the respiration by the phytoplankton cells overnight. In the case of a strong algal bloom this can lead to low dissolved oxygen in bottom waters and in the water column especially in more sheltered locations and/or in the early morning before dawn. Low oxygen can result in metabolic stress for many aquatic organisms. Signs of oxygen stress were not observed in the Waitematā Harbour with oxygen concentration and saturation in the top 30 cm of the water column above guideline levels at all times. However, our monitoring does not resolve seasonal and daily rhythms of both phytoplankton blooms (via chlorophyll *a* concentrations) and dissolved oxygen dynamics (e.g. how frequent are blooms or low dissolved oxygen events and how long do they last). High frequency monitoring via sensor deployment would be required to resolve these dynamics. This could provide information necessary to understand the extent of adverse ecological effects on water quality in the upper Waitematā Harbour due to nutrient pressures.

Preliminary depth profile data at the tidal creek sites, Henderson and Hobsonville collected during summer months in 2023/24 showed that the water column was well mixed and dissolved oxygen concentration remained above 5.7 mg/L at all times and all sites (Auckland Council, unpublished data). However, low dissolved oxygen concentrations have been observed at Rangitōpuni Creek in the past (Ingley 2021). Minimum dissolved oxygen concentrations for upper harbour creek sites ranged between 5.5 and 5.9 mg/L and would be classified as “fair” under the estuarine indicator category for continuous dissolved oxygen seven day mean minimum (see East Coast for further information) (Stevens et al., 2024). Under the “fair” category, moderate stress on aquatic organisms is expected and dissolved oxygen concentrations are below the preference levels for many organisms with a risk of sensitive fish and macrofaunal species being lost (Stevens et al., 2024). This is a conservative interpretation of the dissolved oxygen results but suggests that nutrient stress may be causing early signs of eutrophication in the upper parts of the Waitematā Harbour..

Degrading trends in ammoniacal nitrogen, total oxidised nitrogen and total nitrogen (some sites only) at upper harbour tidal creek sites and Henderson further point towards increased nutrient pressure at these sites. Dissolved oxygen trends over 10- and 15-year periods were decreasing at all sites in the Waitematā Harbour except for Chelsea. Chlorophyll *a* trends were of low confidence in trend direction in the west of the upper harbour and increasing at Lucas Creek and all central harbour sites. The degrading nutrient trends, decreasing dissolved oxygen and increasing (or not improving) chlorophyll *a* concentrations suggests that conditions in the Waitematā Harbour in relation to nutrient pressure are not improving and potentially getting worse.

Modelling results for the Waitematā Harbour showed the largest freshwater nutrient loads to the upper Waitematā Harbour are entering via the Rangitōpuni Creek, Brighams Creek and Henderson Creek (Dudley et al., 2024). This suggests that interventions to reduce loads in these catchments would likely have the most effect on the upper harbour.

Water clarity parameters in the Waitematā Harbour showed spatial patterns of highest concentrations at the upper harbour tidal creek sites and lowest concentrations at the outermost harbour site, at Chelsea. This is consistent with results from previous reports (Kelly and Kamke, 2023; Ingley and Groom, 2022). Similar data ranges for water clarity parameters were found at tidal creek sites and the three mid harbour sites, Henderson, Hobsonville and Whau Creek. The flushing of sediment and organic material from the tidal creek sites into the wider harbour likely requires longer compared to more exposed mid-harbour sites. However, the more exposed location of the mid harbour sites likely leads to greater resuspension of deposited sediment. At Henderson, Green and Hancock (2012) showed that tidal currents and wind waves deposited sediment into the upper reaches of the creek during calm weather. At any location in the harbour our data cannot determine the proportion of inputs from freshwater loading, resuspension and transport from tidal currents and wind waves. Modelling showed that sediment loads from the Rangitōpuni Creek and Henderson Creek catchments are likely the main contributors of freshwater sediment loads in the harbour (Dudley et al., 2024).

Throughout the harbour, turbidity and total suspended solid concentrations were higher from late spring to early autumn when chlorophyll *a* concentrations were also highest. Previous reporting has shown that there are positive correlations between all three water clarity parameters in the Waitematā Harbour (Kelly and Kamke, 2023). This suggests that phytoplankton abundance can influence turbidity and account for some of the total suspended solid concentrations in the

Waitematā Harbour. The proportions of organic matter and sediment affecting water clarity remains unknown. In 2023 Auckland Council started measuring volatile suspended solids in the coastal water quality samples to differentiate inorganic and organic matter from total suspended solids for future reporting.

The seven-year trend analysis showed some spatial differences in water clarity trends in the Waitematā Harbour, with water clarity improving in the upper harbour and degrading in the mid harbour. In the west of the upper harbour (Brigham Creek, Rangitōpuni Creek, Pāremoremo Creek) improving trends for turbidity and total suspended solids were recorded at annual rates of -0.7 to -1.25 mg/L for total suspended solids and -0.2 to -0.5 NTU for turbidity. This indicates reasonable rates of improvement that could result in measurable differences in the next five years if the trend continues. The mid-harbour sites of Hobsonville and Henderson Creek showed degrading trends for chlorophyll *a* and total suspended solids. At Whau Creek all three water clarity parameters had very likely degrading trends at rates, that if confirmed, could also result in measurable differences in the median in five to 10 years. Confirmation of trend results is highly recommended once a longer period of consistent data becomes available. The extreme weather events in 2023 could have impacted the shorter trends, as described in Section 3. Peak sediment loads are expected during high rainfall events and the frequent occurrence of such events in 2023 could have skewed trend results for sediment. In addition, the change of the run order (see Section 2) could have further added to this effect as mid harbour sites were sampled later on the outgoing tide since March 2023. This change was made to better capture land use effects and in the case of high rainfall events would have a stronger impact on the data. However, increasing trends in turbidity were previously reported at mid Waitematā Harbour sites (Ingley, 2021) supporting the possibility of reduced water clarity at these sites.

Overall, our data showed potential degradation for both nutrient and water clarity parameters at Waitematā Harbour sites. Further investigations are needed to understand the drivers for the observed changes in the Waitematā Harbour. Land use changes occurred in recent years (from 2018 to 2023) in many northern catchments draining to the Waitematā Harbour (Auckland Council, 2025). The most prominent was the conversion of 789 ha (~1.8 per cent per cent of the whole harbour catchment) from various land uses (including exotic grassland, exotic and native forest) to urban area. Most of these changes occurred in the western part of the catchment closest to Hobsonville and Henderson sampling sites, and to a lesser degree in the Lucas Creek catchment. Some conversion of cropping and horticulture land to exotic grassland was also recorded. Conversion of exotic grassland to indigenous forest and shrubland took place in the wider Rangitōpuni Catchment. While the current monitoring programme is not set up to specifically attribute changes in water quality to a particular change in land use or activity, sites in the upper Waitematā Harbour might be useful study sites for more targeted cause and effects monitoring.

6 Tāmaki Estuary

6.1 Background

Tāmaki Estuary is a shallow drowned valley following the estuary type classification of Hume et al. (2016) and has a surface area of 17 km^2. The catchment area is about 102 km^2 and highly populated with predominantly urban land cover (92 per cent) (Auckland Council, 2025). Since the last report (Ingley, 2021), small areas of exotic grassland and urban parkland in the Otara Creek/Flat Bush and Pakuranga Creek sub-catchments were converted to urban land cover.

6.2 State and Trend Results

6.2.1 Physical parameters

Data ranges for most physical parameters were similar at the two Tāmaki Estuary sites (Figures 6-1 and 6-2). Water temperature medians fell at 17.6°C to 18.0°C and temperature ranged at both sites from approx. 12°C to 24.5°C. There was only a slight difference in salinity and pH between these sites, as the Panmure site (median salinity: 31 ppt, median pH: 7.9) was exposed to slightly greater freshwater influence than the Tāmaki site (median salinity: 32 ppt, median pH: 8.0). At the Tāmaki sampling site, dissolved oxygen saturation (median: 99.1 per cent) and concentrations (median: 7.9 mg/L) were slightly higher than at Panmure (median saturation: 96.7 per cent, concentration: 7.7 mg/L) and both sites were well within guideline values (Figure 6-1).

The confidence in trend direction for water temperature was low at Panmure whereas likely decreasing trends were observed at Tāmaki based on seven-year trends (Figure 6-2). For longer trend periods (10 and 15 years), confidence in temperature trends increased. Trend direction was very likely increasing at both sampling sites with annual Sen slopes indicating an increase in temperature of approx. 0.1°C per year (Figure 6-2). Based on the seven-year trends, very likely and likely decreasing trends were also estimated for salinity and pH at both sites (Figure 6-2). A distinct drop in salinity was observed during the 2023 hydrological year, likely associated with high rainfall. Longer trend periods of 10 and 15 years confirmed decreasing trends in salinity but showed likely to very likely increasing trends in pH at both sites. For dissolved oxygen parameters seven-year trends were likely to very likely increasing at low magnitudes (Figure 6-2), which were consistent with 10- and 15-year trends.

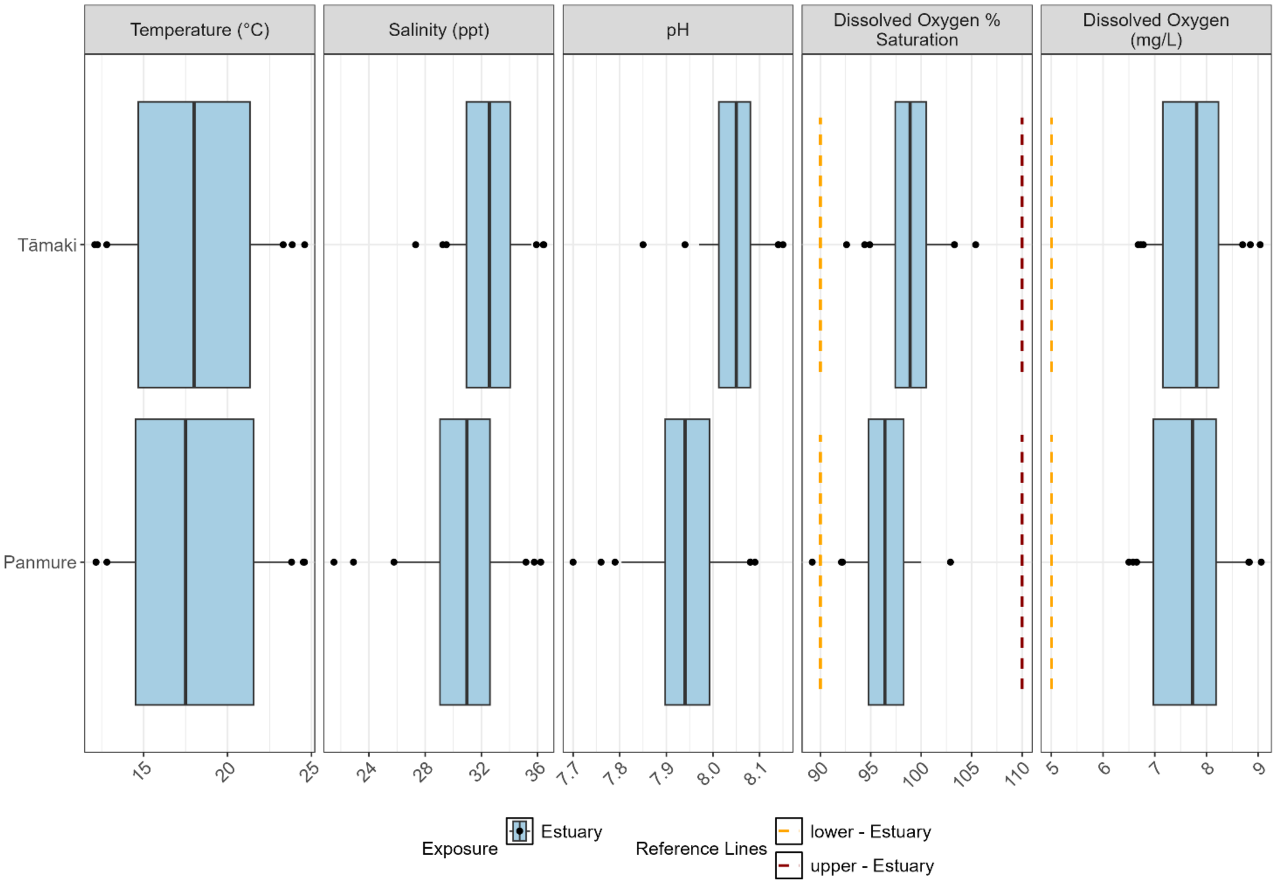

Figure 6-1. Boxplots showing physical parameters at Tāmaki Estuary monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2.

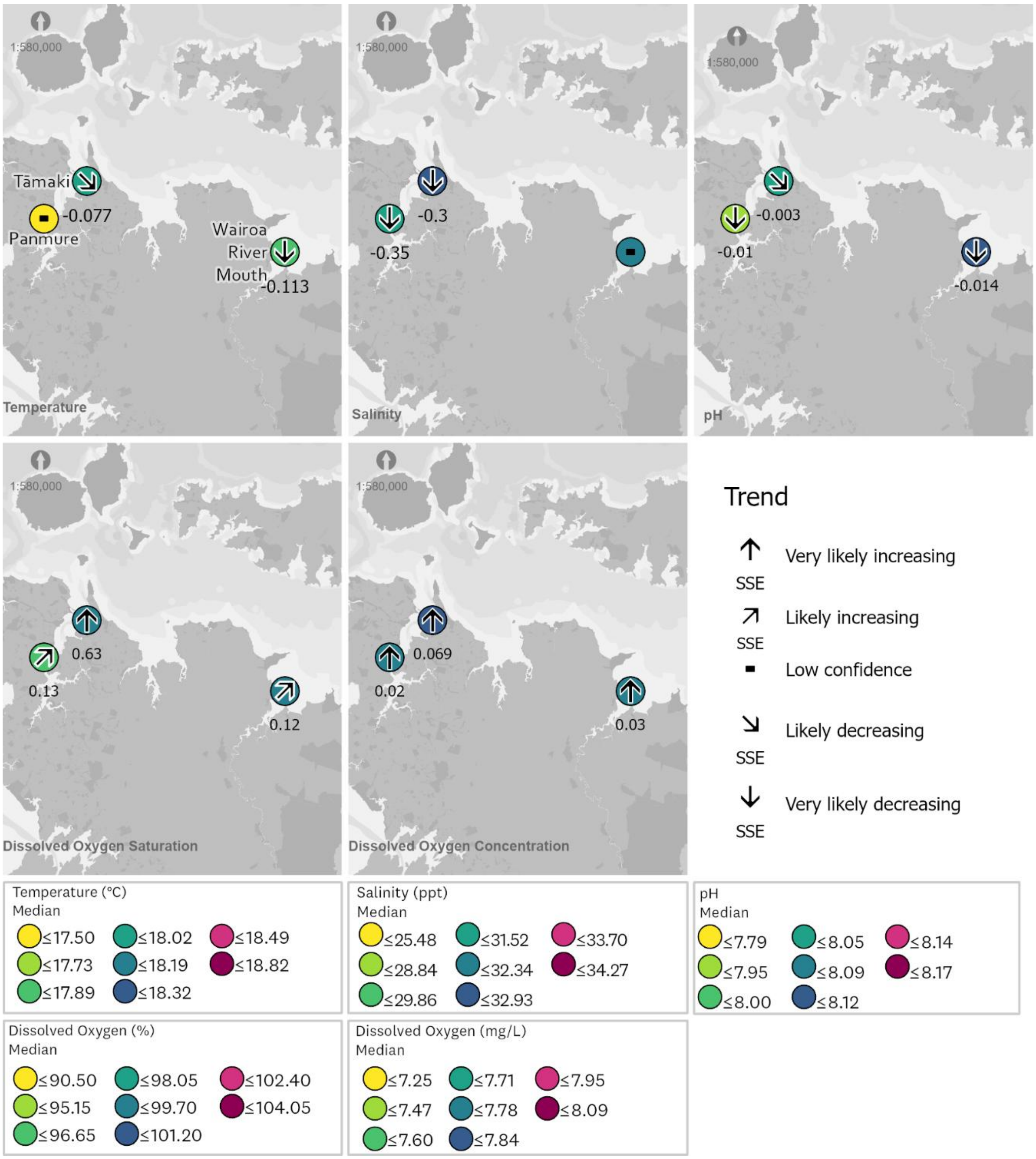

Figure 6-2. Maps showing state (2020 to 2024 median) and seven-year trend (2018 to 2024) information for physical parameters at Tāmaki Estuary monitoring sites. The Sen slope estimator (SSE) displays the annual Sen slope in the unit of the corresponding parameter.

6.2.2 Nutrients

Nutrient concentrations in the Tāmaki Estuary were generally higher at the upper estuarine site at Panmure compared to the Tāmaki site in Half Moon Bay (Figure 6-3 and 6-4). Median ammoniacal nitrogen concentrations exceeded the guideline value at both sites (Figure 6-3). At Panmure, total oxidised nitrogen concentrations did not exceed the guideline based on the five-yearly median. However, closer inspection of monthly medians over the same period showed exceedances in late autumn and winter (May to July and September) of up to three-fold (Appendix D, Figure D-5). Seasonal guideline exceedances (January, March to July) were also detected at Panmure for dissolved reactive phosphorus and total phosphorus in January to March and June. All exceedances were of low magnitude, approximately 1.2 times the guideline value.

Trend analysis indicated very likely improving trends for all nutrient parameters at the Tāmaki sampling site (Figure 6-4). The magnitudes of these trends were low: annual Sen slopes ranged from -0.0005 mg/L for total oxidised nitrogen to -0.007 mg/L for total nitrogen. At Panmure, total nitrogen and dissolved reactive phosphorus trends were also very likely improving, while ammoniacal nitrogen was likely improving and the confidence in trend direction for total oxidised nitrogen was low (Figure 6-4). The trend magnitude for total nitrogen at Panmure (annual Sen slope: -0.018 mg/L) was higher than at Tāmaki but trend magnitudes for ammoniacal nitrogen (annual Sen slope: -0.0005 mg/L) and dissolved reactive phosphorus (annual Sen slope: -0.0006 mg/L) were low, similar to those at the Tāmaki site (Figure 6-4).

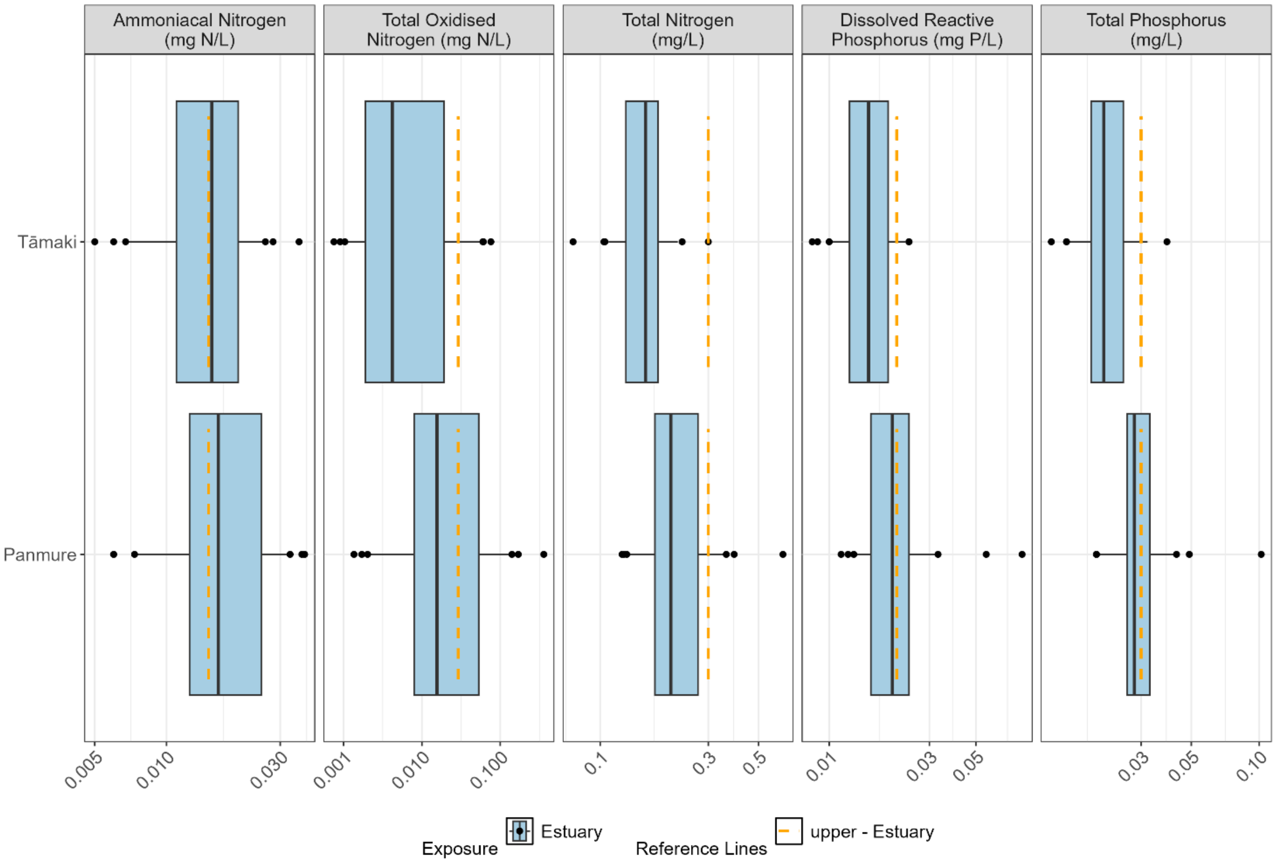

Figure 6-3. Boxplots showing nutrient parameters at Tāmaki Estuary monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2. X-axis is shown at log scale.

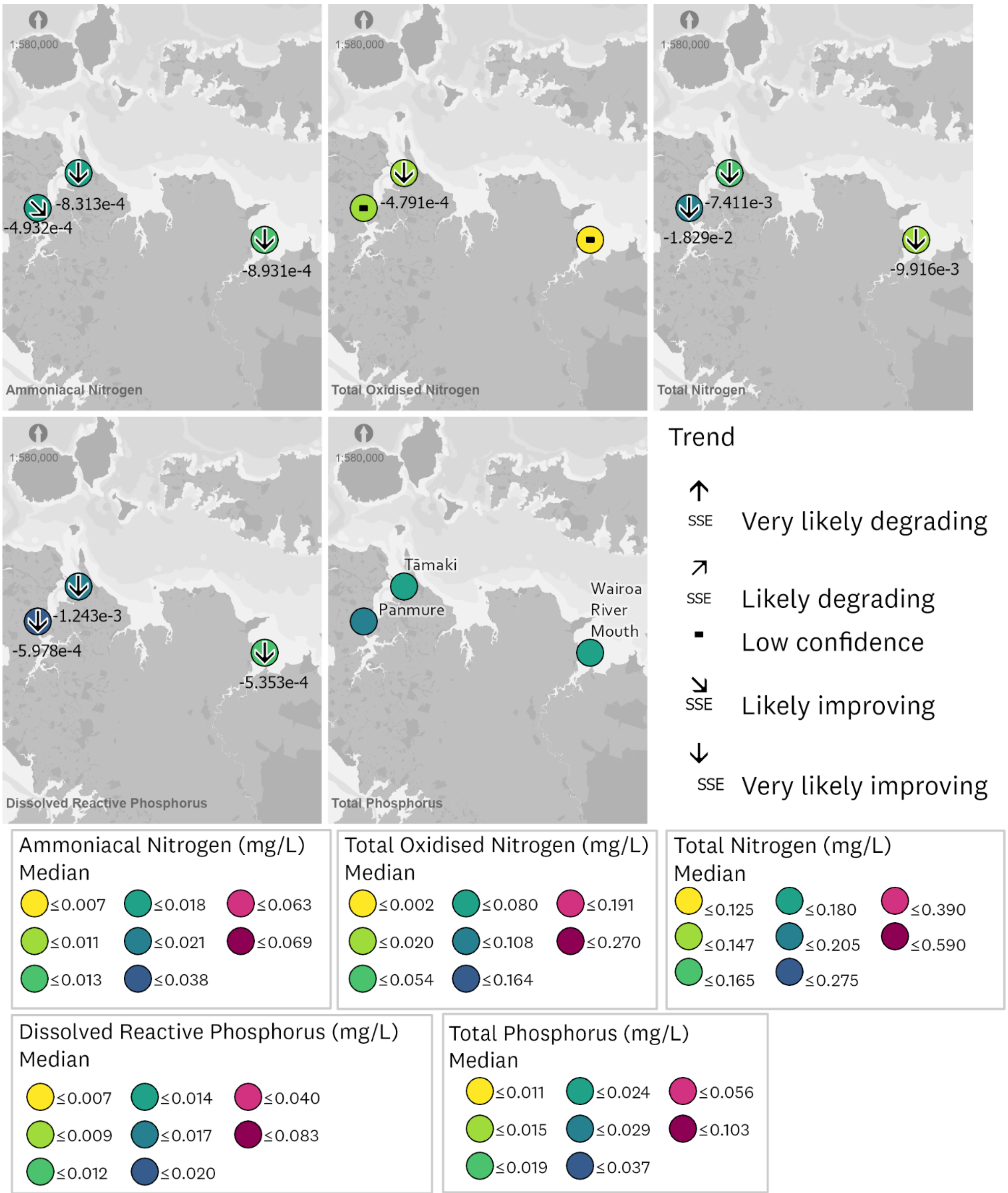

Figure 6-4. Maps showing state (2020 to 2024 median) and seven- year trend (2018 to 2024) information for nutrient parameters at Tāmaki Estuary monitoring sites. The Sen slope estimator (SSE) displays the annual Sen slope in the unit of the corresponding parameter.

6.2.3 Water clarity

Data ranges for all water clarity parameters were higher at Panmure than Tāmaki (Figure 6-5 and 6-6). Median concentration in the 2020 to 2024 reporting period were between 1.5 (chlorophyll *a*) to 2 times (turbidity) higher at Panmure than at Tāmaki. Five-yearly and monthly medians remained below guideline values for both chlorophyll *a* and turbidity at both sites. The extreme weather events in February 2023 resulted in chlorophyll *a* concentrations at Panmure of 0.0075mg /L, the highest measured across the current reporting period. Such increases were not observed for turbidity or total suspended solids, or in chlorophyll *a* at the Tāmaki monitoring site. In March 2022 a single high value in chlorophyll *a* (0.04 mg/L) caused a spike in the Tāmaki dataset which caused the only exceedance of the monthly 90th percentile of the relevant chlorophyll *a* guideline.

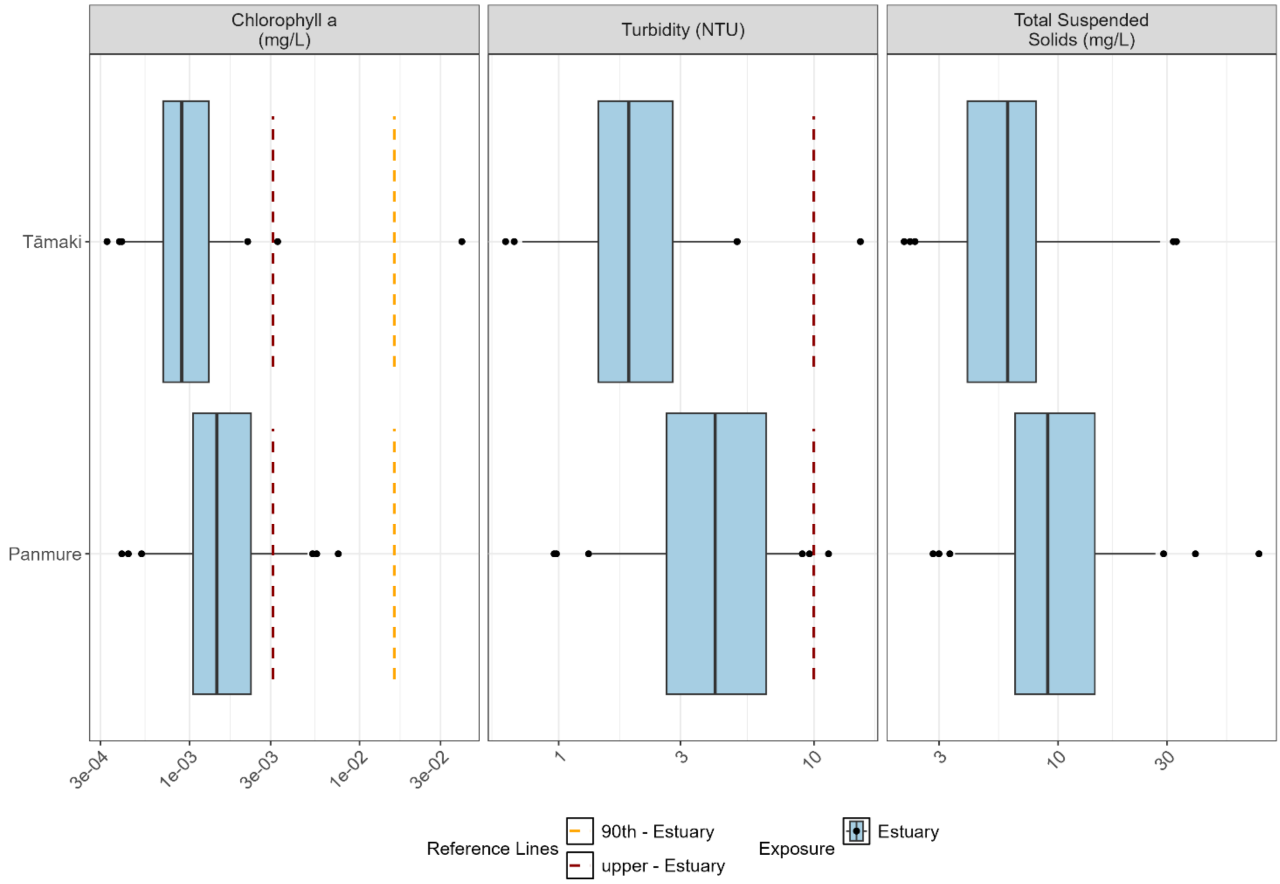

Figure 6-5. Boxplots showing water clarity parameters at Tāmaki Estuary monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2. The x-axis is shown at log scale.

Trend analysis for water clarity parameters in the Tāmaki Estuary showed differing directions and magnitudes of change between the two monitoring sites (Figure 6-6). All water clarity parameters were very likely improving at Panmure. Rates of improvement for turbidity (annual Sen slope: -0.37 NTU) and total suspended solids (annual Sen slope: -0.74 mg/L) were reasonably high. In contrast, at Tāmaki chlorophyll *a* trends were likely degrading, turbidity trends were likely improving and for total suspended solids, there was low confidence in the trend direction. Both chlorophyll *a* and turbidity trends were of lower magnitude at Tāmaki compared to Panmure (Figure 6-6).

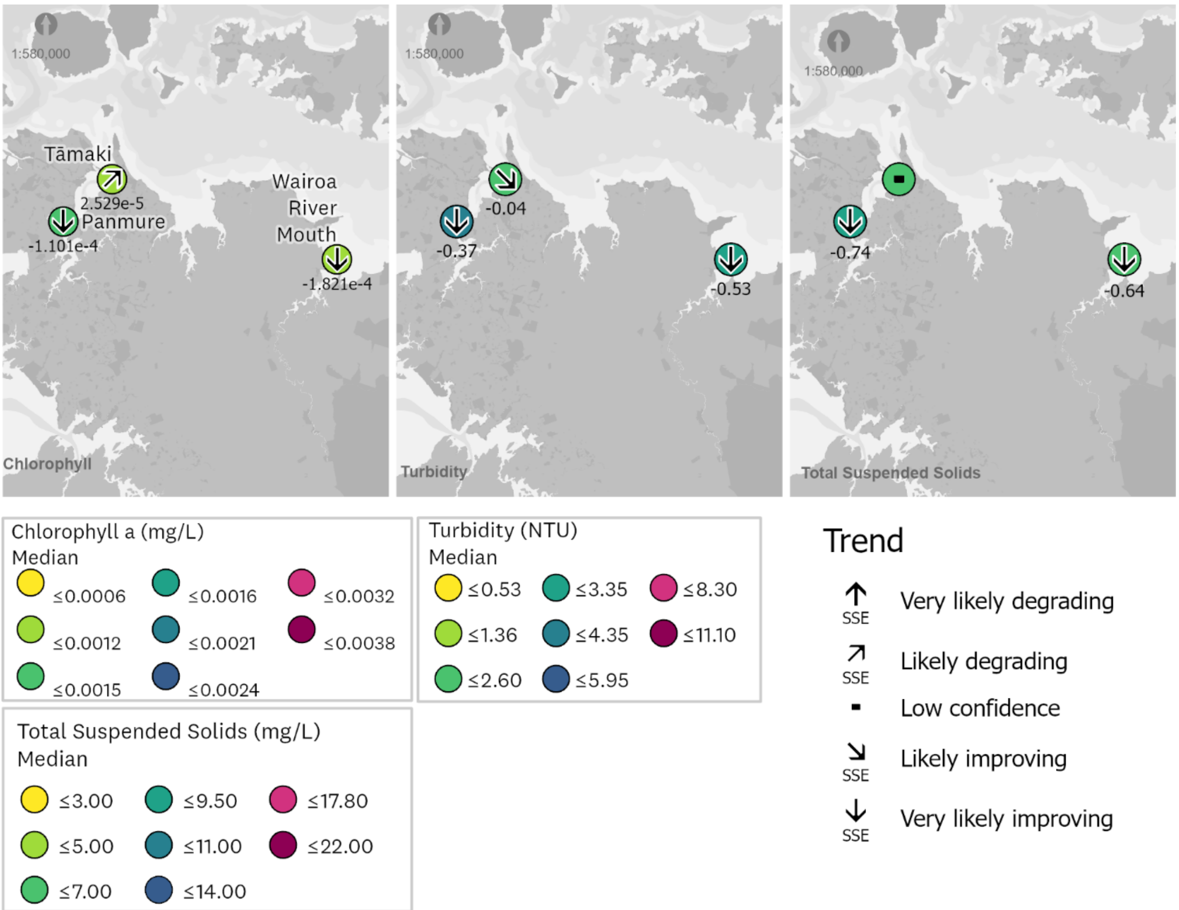

Figure 6-6. Maps showing state (2020 to 2024 median) and seven-year trend (2018 to 2024) information for water clarity parameters at Tāmaki Estuary monitoring sites. The Sen slope estimator (SSE) displays the annual Sen slope in the unit of the corresponding parameter.

6.3 Discussion

Monitoring of physical parameters showed that upper estuary Panmure site was more strongly influenced by freshwater with slightly lower salinity and pH compared to the more exposed Tāmaki monitoring site. These results were consistent with previous reporting (Kelly and Kamke, 2023; Ingley 2022). As described in Section 3, the seven-year trend period was influenced by unusual weather conditions with less rainfall at the beginning of the trend period and more rainfall towards the end. This likely impacted the trend seen for physical parameters in the Tāmaki Estuary. Seven-year trends showed lower confidence in trend direction for water temperature and 15-year trends confirmed the increasing trend direction previously reported by Ingley (2021). The rate of the increase was approximately 0.05°C lower in this report compared to the magnitudes reported in the last trend report, which were considered unusually high for the area (Ingley 2021). Future reporting will need to confirm the rate of change in water temperature in the Tāmaki Estuary.

Decreasing salinity for all trend periods was consistent with the findings of previous reporting (Ingley, 2021) and the regional direction of salinity trends (Section 3). This is likely associated with increased rainfall across all trend periods. Overall, the climatic conditions seem to have affected seven-year trends in salinity more than 10 and 15-year trends. It is therefore reasonable to assume that seven-year trends for nutrient and water clarity parameters were also impacted by increased rainfall. All seven-year trends should therefore be seen as indicative direction in water quality and be confirmed once a longer consistent data record for trend analysis become available.

Nutrient concentrations were consistently higher at the Panmure monitoring site than at the Tāmaki monitoring site. This is likely driven by more direct freshwater impacts at Panmure as it is in the upper estuary and closer to discharges from the catchment. At both sites ammoniacal nitrogen concentrations exceeded the guideline value. This is consistent with previous reporting where most monthly guideline exceedances were caused by high ammoniacal nitrogen concentrations (Ingley and Groom 2022). Our monitoring showed additional guideline exceedances at Panmure for total oxidised nitrogen, dissolved reactive phosphorus and total phosphorus, indicating some nutrient pressure. Chlorophyll *a* and dissolved oxygen data did not show signs of nutrient enrichment at either site. Our trend results showed improvement in nutrient concentrations in the Tāmaki Estuary with predominantly improving trends for all parameters at both sites. The previous state and trends report showed degrading trends for ammoniacal nitrogen at both sites and for dissolved reactive phosphorus at the Tāmaki site. Ammoniacal nitrogen trends were impacted by step changes in the data in the previous report explaining the observed differences. The degrading trend in dissolved reactive phosphorus for the 2010-2019 period was of relatively low magnitude (<0.0003 mg/L) whereas the improving trend in this report had a relatively high magnitude of -0.001 mg/L, which if confirmed would lead to a measurable improvement in state by the time of the next state and trends report in 2030.

While this report did not find evidence of ecological impacts from nutrient enrichment across both sites in the Tāmaki Estuary, it is possible that the upper reaches of the estuary are experiencing some nutrient stress. Our monitoring shows higher nutrient concentrations at Panmure than at the Tāmaki site – and even higher concentrations could be expected upstream of Panmure. Modelling estimated at least twice the concentrations of total nitrogen and total phosphorus in the narrow inlets of the upper estuary in comparison to the estimates for the Panmure monitoring site (Dudley et al., 2024). The Otara Creek was identified as a major source for both total nitrogen (48 per cent of the overall total nitrogen load) and total phosphorus (30 per cent of the overall total phosphorus load) in the upper Tāmaki Estuary (Dudley et al., 2024). The Otara Creek drains the largest catchment (34.81 km^2) into the Tāmaki Estuary with the Pakuranga Creek draining the second largest catchment (28.82 km^2) and was identified by modelling as the second highest freshwater source of total nitrogen (21 per cent of the overall load) and total phosphorus (9 per cent of the total load) in the upper estuary (Dudley et al., 2024). Catchment size is likely a key factor for nutrient loading in these urban catchments.

Signs of impact on dissolved oxygen concentration in the upper estuary were also shown in a recent report. High frequency dissolved oxygen monitoring data revealed that dissolved oxygen minima at Otara Creek were driven by the incoming tide (Young et al., 2025). The dissolved oxygen one-day minimum and the seven-day mean minimum for the 2020 to 2024 reporting period were low at 0.2 mg/L and 0.72 mg/L, respectively. This indicates that low dissolved oxygen concentrations are likely occurring in either the tidal sections of the Otara Creek or the upper parts of the Tāmaki Estuary. It is therefore possible that our state of the environment monitoring programme for coastal water quality is not entirely capturing effects on dissolved oxygen in the Tāmaki Estuary. Targeted investigations are necessary to gain a better understanding of the dissolved oxygen dynamics in the upper estuarine area and whether these are related to nutrient enrichment or other issues such as breakdown of organic matter. There were very few guideline breaches for water clarity parameters at both sites in the Tāmaki Estuary indicating high visual clarity in the estuary. The Panmure site was slightly more turbid and showed higher chlorophyll *a* concentrations. This is expected as exposure to nutrient and sediment sources are higher at this upper estuarine site. There was stronger evidence of improvement in water clarity at the Panmure site compared to the Tāmaki site based on all three parameters. This was consistent with previously reported improving trends for chlorophyll *a* and turbidity over the 2010 to 2019 monitoring period (Ingely 2021). Total suspended solid trends also showed that further improvements in water clarity state can be expected in future reporting.

At Tāmaki, trends for chlorophyll *a* and turbidity were less certain in trend direction and did not align with previous reporting. In the 2010 to 2019 trend period the chlorophyll *a* trend was very likely improving (Ingley, 2021) but was likely degrading for this reporting period (2017 to 2024). Chlorophyll *a* trends assessed in the previous period may have been influenced by the change in detection limit in July 2017 as the results of a change in laboratory, adding uncertainty to the trend findings. However, the seven-year trends in this report are more strongly impacted by weather events (see Section 3), and so there is uncertainty as to whether the degrading trends for chlorophyll *a* and other clarity parameters will continue over a longer period. For turbidity at the Tāmaki site, Ingley (2021) reported very likely improving trends at a magnitude of ~ -0.2 NTU per year while in this analysis, confidence in the improving trend direction was lower (likely, rather than very likely) and the magnitude of trend was also lower at - 0.04 NTU per year. There was therefore uncertainty in both trend assessments and trend assessments over longer periods of consistent data will be required to understand the direction and rate of change in water clarity parameters at the Tāmaki monitoring site.

7 Wairoa River Mouth

7.1 Background

The Wairoa River begins in the Hunua Ranges and drains into the Tāmaki Strait. The Wairoa River catchment covers an area of approximately 297 km^2. Most of the catchment land use is pastoral with 53 per cent exotic grassland, 21 per cent indigenous forest, 16 per cent exotic forest and eight per cent shrubland (Figure 2-2). Changes in land cover since the last report were small (less than three per cent of the total catchment) and were mainly in form of conversion of exotic grassland to indigenous forest, shrubland and urban areas (Auckland Council, 2025).

7.2 State and Trend Results

7.2.1 Physical parameters

In the 2020 to 2024 monitoring period, no unusual measurements in physical parameters were recorded at Wairoa River Mouth (Figure 7-1). Water temperature ranged from 11°C to 25°C with median values at 18°C. Salinity was above 30 ppt more than 75 per cent of the time with a median of 32 ppt. Slight drops in salinity were mainly observed during a period of strong rainfall from spring 2022/23 to early winter 2023. Median pH was 8.1 and ranged from 8.0 to 8.3. Water was well oxygenated as dissolved oxygen concentrations were well within guideline values with a saturation range from 93 per cent to 109 per cent and dissolved oxygen concentrations above 6 mg/L at all times (Figure 7-1).

Seven-year trends for physical parameters are shown in Figure 6-2. Trends in temperature and pH were very likely decreasing over the seven-year trend period. Over a 15-year period, the trend direction changed to very likely increasing for both parameters. The confidence in the trend direction of the seven-year salinity trend was low but changed to very likely decreasing for the 15-year trend period. Trends for both dissolved oxygen concentration and saturation were likely to very likely increasing for seven-year trends but of low confidence in trend direction for 15-year trends.

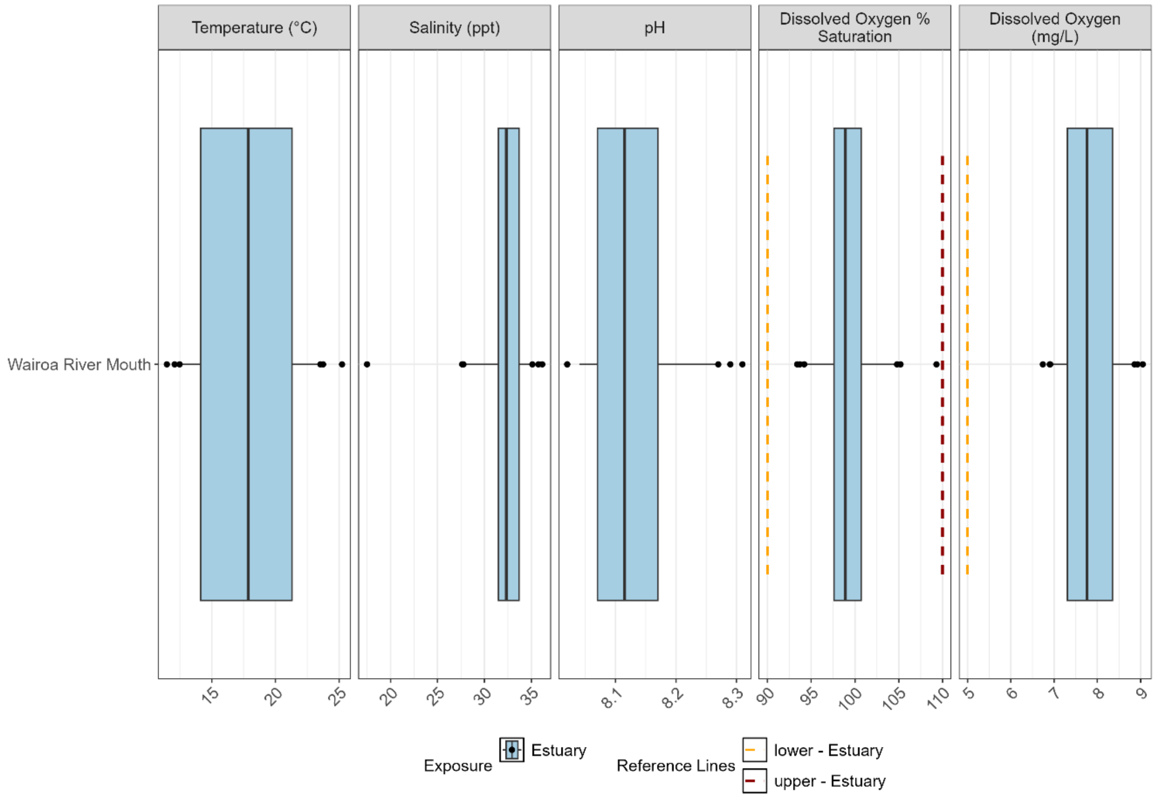

Figure 7-1. Boxplots showing physical parameters at Wairoa River Mouth for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2

7.2.2 Nutrients

Five-yearly median values at Wairoa River Mouth remained below guideline values for all nutrient parameters (Figure 7-2). Monthly median values for ammoniacal nitrogen exceeded the guideline slightly in August and September (Appendix D, Figure D-6). Seven-year trends analysis revealed very likely improving trends at low rates for ammoniacal nitrogen (annual Sen slope: -0.0009 mg/L), total nitrogen (annual Sen slope: -0.01mg/L), and dissolved reactive phosphorus (annual Sen slope: -0.0005 mg/L). There was low confidence in the trend direction for total oxidised nitrogen (Figure 6-4).

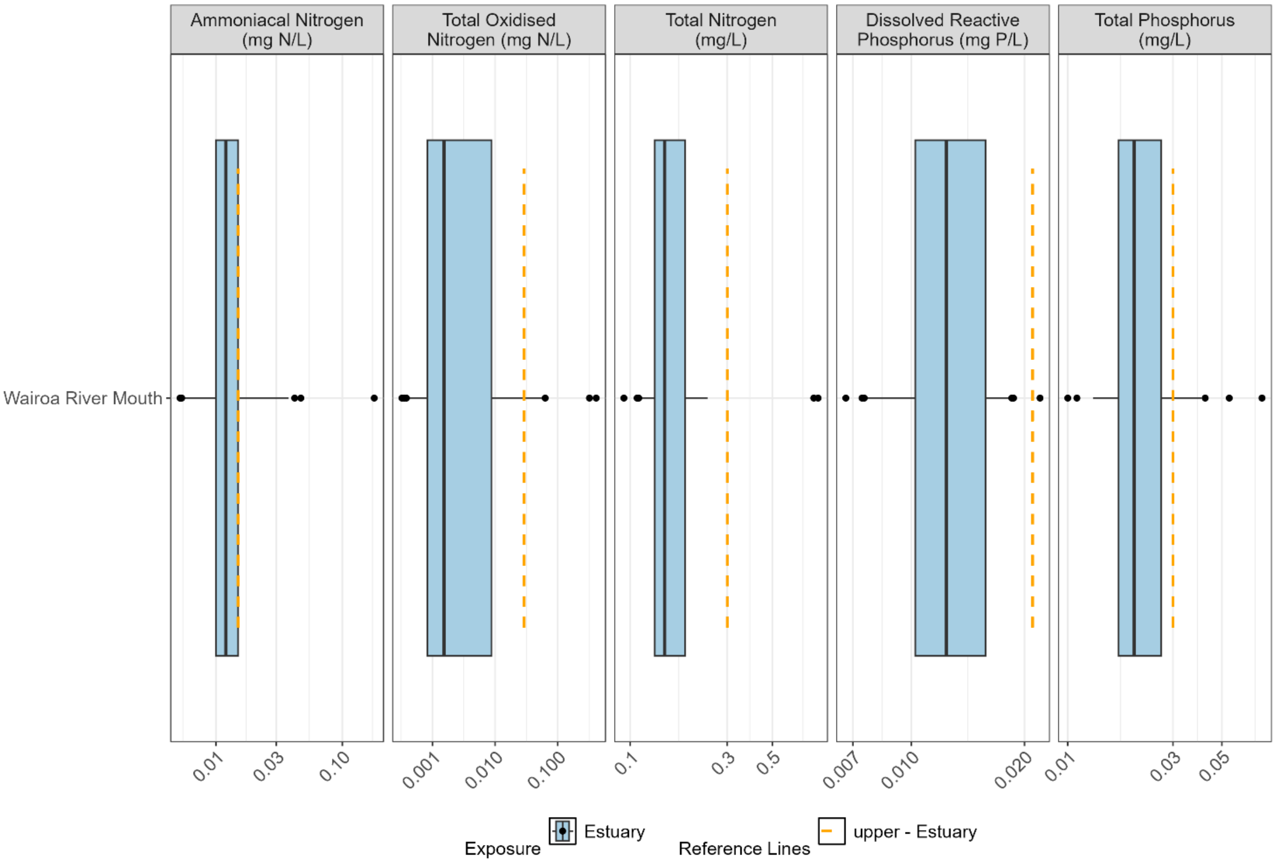

Figure 7-2. Boxplots showing nutrient parameters at Wairoa River Mouth for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2. The x-axis is shown a log scale.

Visual inspection of nutrient timeseries data showed some noticeable changes in nutrient concentrations in the second half of 2022. There was a drop in dissolved reactive phosphorus from values close to 0.017 mg/L to concentrations around 0.0075mg/L and lower in July 2022. Dissolved reactive phosphorus values remained low until December 2023. These lower values were also observed in total phosphorus and total nitrogen for the same time period but to a lesser degree. However, in May 2023 there was a distinct increase in nutrient concentrations for total nitrogen, total phosphorus and total oxidised nitrogen together coinciding with a drop in salinity. Ammoniacal nitrogen and dissolved reactive phosphorus did not increase at this occasion.

7.2.3 Water clarity

All water clarity parameters remained under guidelines values at Wairoa River Mouth during the 2020 to 2024 reporting period (Figure 7-3). Low median values for all three parameters were observed including total suspended solids (7 mg/L), turbidity (2.8 NTU), and chlorophyll *a* (0.0012 mg/L). Occasional increases in water clarity parameters coinciding with decreases in salinity and nutrient increases were observed to varying degrees during the seven-year trend reporting period including in June 2020, October 2022 and May 2023 (Figure 7-4). However, the frequency and magnitude of peaks in e.g. total suspended solids appear to have decreased since early 2021. Before 2021 total suspended solid peaks were not always recorded at the same time as drops in salinity. Trends for all three water clarity parameters were very likely improving (Figure 6-6) at rates of 0.64 mg/L for total suspended solids, 0.5 NTU for turbidity and 0.0002 mg/L for chlorophyll α .

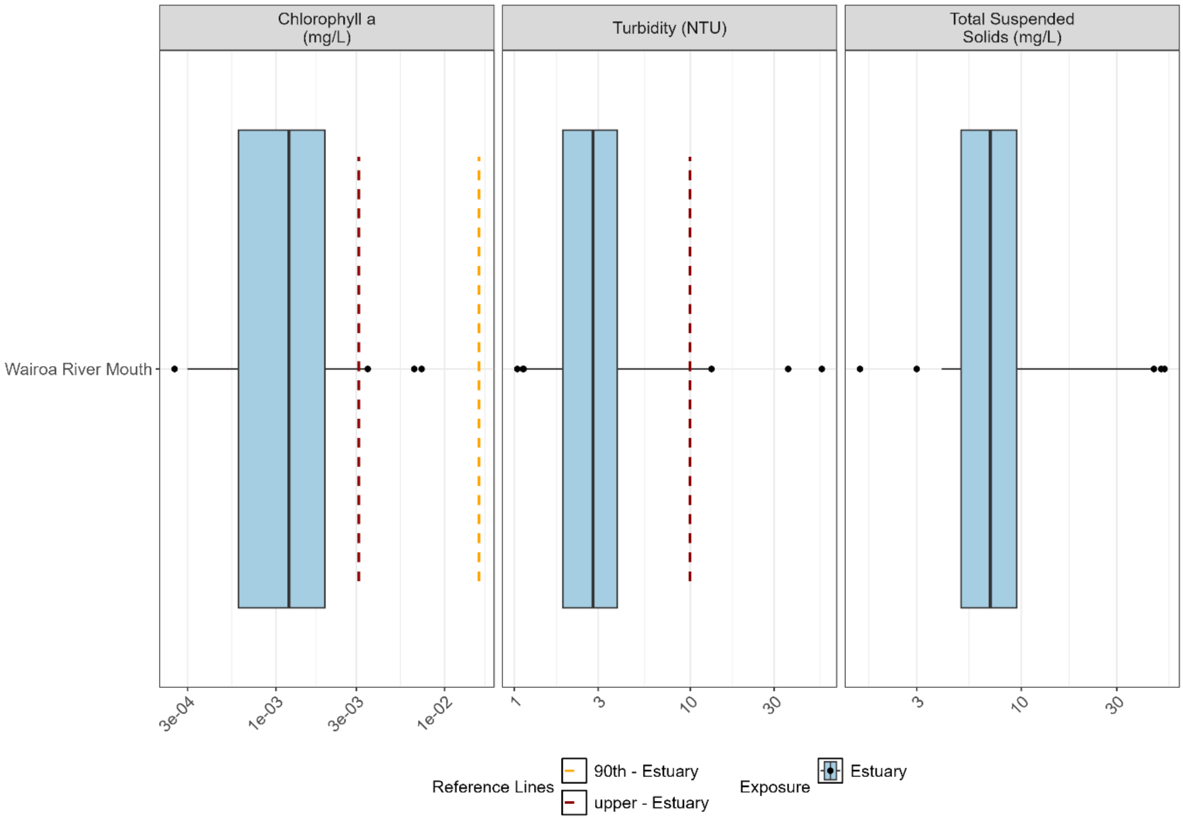

Figure 7-3. Boxplots showing water clarity parameters at Wairoa River Mouth for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2. The x-axis is shown at log scale.

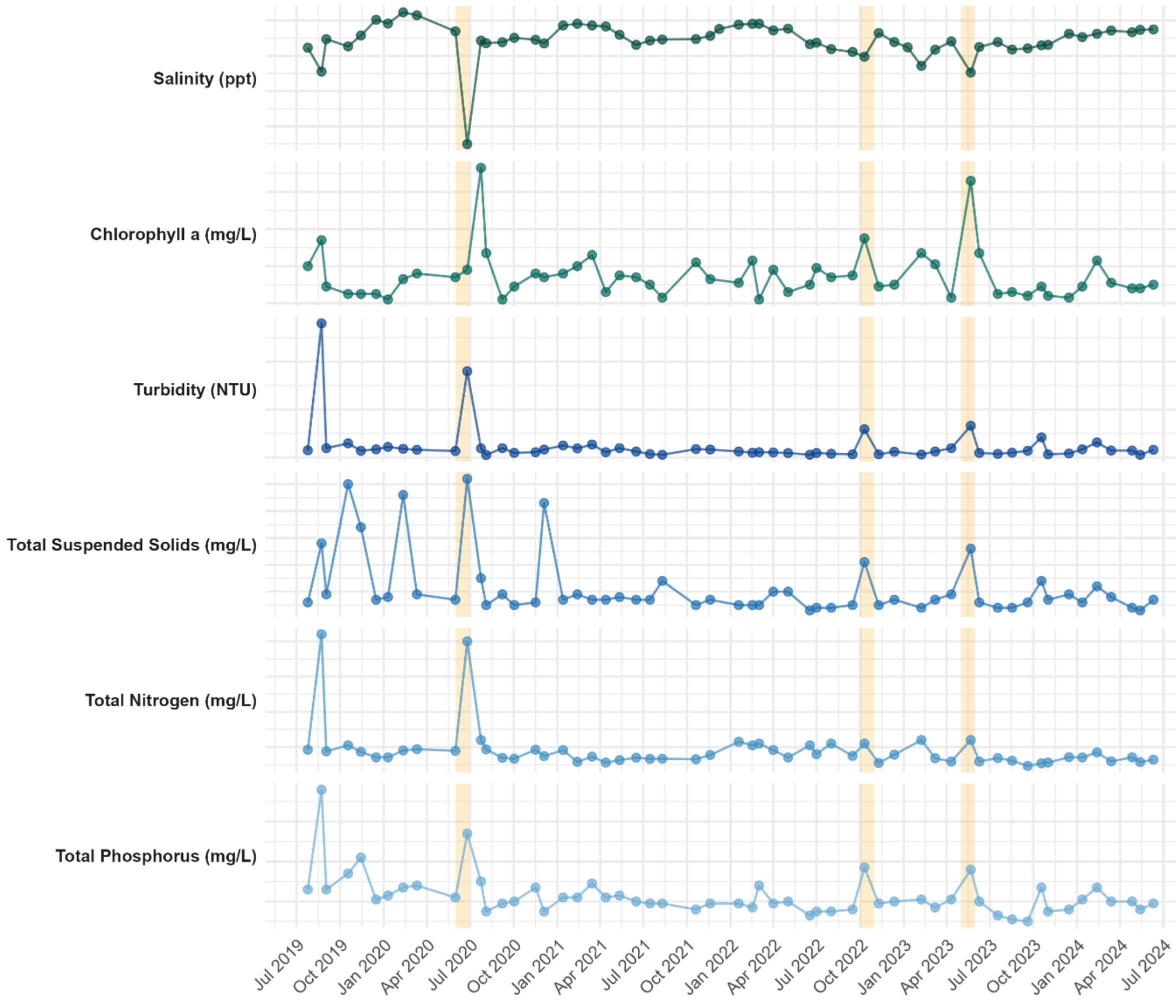

Figure 7-4. Time series data for salinity, nutrient and water clarity parameters at Wairoa River Mouth. Incidents of high concentrations of water clarity and nutrient parameters with decreased salinity are highlighted.

7.3 Discussion

Physical water quality parameter data ranges for the current reporting period were comparable to those reported previously (Kelly and Kamke 2023, Ingley 2022). Some effects of generally wet climate at the end of 2022 to mid-2023 were seen in lower salinity during this period. A general decrease in salinity was reflected in 15-year trend results as for many sites in the region (see Section 3). Water temperature and pH also showed the same shift in trend direction as reported in the regional summary (Section 3), i.e., from decreasing trends over seven-years to increasing trends over 15-years.

Improvements since the previous report were seen for the state of nutrients and water clarity. In previous monitoring periods, exceedances of water quality guidelines were more frequent and affected more parameters (Ingley and Groom, 2022; Ingley, 2021). The improvement in nutrient concentrations for most parameters and all water clarity parameters was confirmed by very likely improving trends. In a rural catchment, like that of the Wairoa River, it would be expected to see at least some increases in nutrient parameters and turbidity in wet weather periods, as seen for the current reporting period. Higher rainfall increases the nutrient loading from diffuse sources such as leaching from land with high fertiliser use and erosion in the catchment leading to rapid accumulation of sediment during storm events (Green et al., 2021). Our data showed such impacts occasionally but large peaks in nutrient and water clarity parameters during the period of frequent heavy rain events in late 2022 to mid-2023 were not observed and high peaks in total suspended solid concentrations did not always coincide with decreases in salinity. Salinity data show that at the Wairoa River Mouth monitoring site conditions are usually euhaline (salinity >30 ppt). This showed that the site was likely well flushed and could be one reason why the water here shows low impacts from nutrients and sediment.

The timing of our sampling may also not capture the full effects of storm events. Safety requirements do not allow for monitoring directly during storm events and it is possible that event-based impacts on water quality are missed in our monitoring. High frequency monitoring equipment was installed at the Wairoa River Mouth as part of the National Institute of Water and Atmospheric Research's (NIWA) 'Managing Mud' programme. The programme aimed to investigate river sediment loads with suspended sediment in the estuary. It was shown that peak suspended sediment concentrations in the estuary during storm events were driven by sediment coming down the river (rather than wave resuspension) causing a fine sediment plume (Rautenbach et al., 2024). Peak suspended sediment concentrations were measured (and predicted by modelling) upstream of the river mouth. At the site closest to the Wairoa River Mouth SOE monitoring site suspended sediment concentrations of more than 600 mg/L were measured (and predicted by modelling) during a storm event in 2018 (Rautenbach et al., 2024). This demonstrates the need for high frequency monitoring instruments to capture suspended sediment dynamics in estuaries such as the Wairoa River Mouth Estuary.

8 Manukau Harbour

8.1 Background

The Manukau Harbour is Aotearoa / New Zealand's second-largest estuary, covering a surface area of 366 km² and draining a relatively small catchment of 916 km². Land use across the catchment varies significantly: the north is dominated by indigenous forest and scrub/shrubland (part of the Waitākere Ranges), the east is largely urban and the southern part of the catchment land cover is primarily exotic grassland and cropland (Auckland Council, 2025). Within this southern part, the area around Pukekohe is known for vegetable production and associated fertiliser use. Over time, this has caused high nitrate concentrations in groundwater and in the rivers discharging to the southern Manukau Harbour (Morgenstern et al., 2023).

While land use has remained largely unchanged in the northern and western areas since the last report, small shifts have occurred in the eastern and southeastern parts of the catchment. Of note is the conversion of exotic grassland to urban (built-up) areas around Drury (Auckland Council, 2025).

The Manukau Harbour also receives the discharge from the Māngere wastewater treatment plant which treats approximately 75 per cent of Auckland's municipal wastewater. In the south of the harbour, effluent from several smaller wastewater treatment plants at Kingseat, Waiuku, and Clarks Beach are also discharged into the Manukau Harbour. These all have potential to influence the water quality in the estuary, along with diffuse pollution related to land use.

8.2 State and Trend Results

8.2.1 Physical parameters

Water temperature ranges and median values (18 to 19°C) were similar across the Manukau Harbour. Manukau Heads had a slightly narrower temperature range with a slightly lower median for the 2020 to 2024 monitoring period (Figures 8-1 and 8-2). The confidence in trend direction for water temperature was low at all sites (Figure 8-2). Extending the trend period to 15 years showed likely (Waiuku Town Basin) and very likely increasing temperature trends (all other sites) consistent with general observations for the Auckland region (Section 3).

Salinity showed a spatial gradient throughout the harbour with the highest median value and narrowest data range at the harbour entrance (Manukau Head), lower salinity at outer/mid harbour sites, even lower salinity at upper harbour sites. The lowest median salinity concentration and largest salinity range were at the upper harbour site at Waiuku Town Basin (Figures 8-1 and 8-2). This spatial gradient was also observed for pH data but data ranges at some sites were slightly skewed (Figure 8-1). For example, at Clarks Beach and Waiuku Town Basin median pH seemed low compared to sites with similar salinity (e.g. Shag Point). Trends in salinity and pH were likely or very likely decreasing across the harbour with the exception of salinity at Waiuku Town Basin where the confidence in trend direction was low (Figure 8-2). The trend direction for salinity over 15-year trends period was decreasing at all sites except Waiuku Town Basin, where confidence in trend direction was likely increasing. Trends for pH over 15 years were likely to very likely increasing at all sites.

Dissolved oxygen concentrations remained above the 5 mg/L guideline level for all sites. While median concentrations also stayed within dissolved oxygen saturation guidelines, upper and lower percentiles breached either the upper or lower guideline or both at all sites except at Manukau Heads (Figure 8-1). At Waiuku Town Basin the monthly median dissolved oxygen saturation in March breached the lower guideline value of 90 per cent (Appendix D, Figure D-7). Oxygen trends differed in trend direction throughout the harbour (Figure 8-2) and often the confidence in trend direction was low for at least one oxygen parameter. Longer trend periods of 10 and 15 years did not increase confidence in trend direction at many sites or changes in trend direction between the two oxygen parameters were observed (Appendix C, Supplementary data file 2). Where trend direction could be determined, trend magnitudes for dissolved oxygen parameters were low throughout the harbour (Figure 8-2 and Appendix C, Supplementary data file 2).

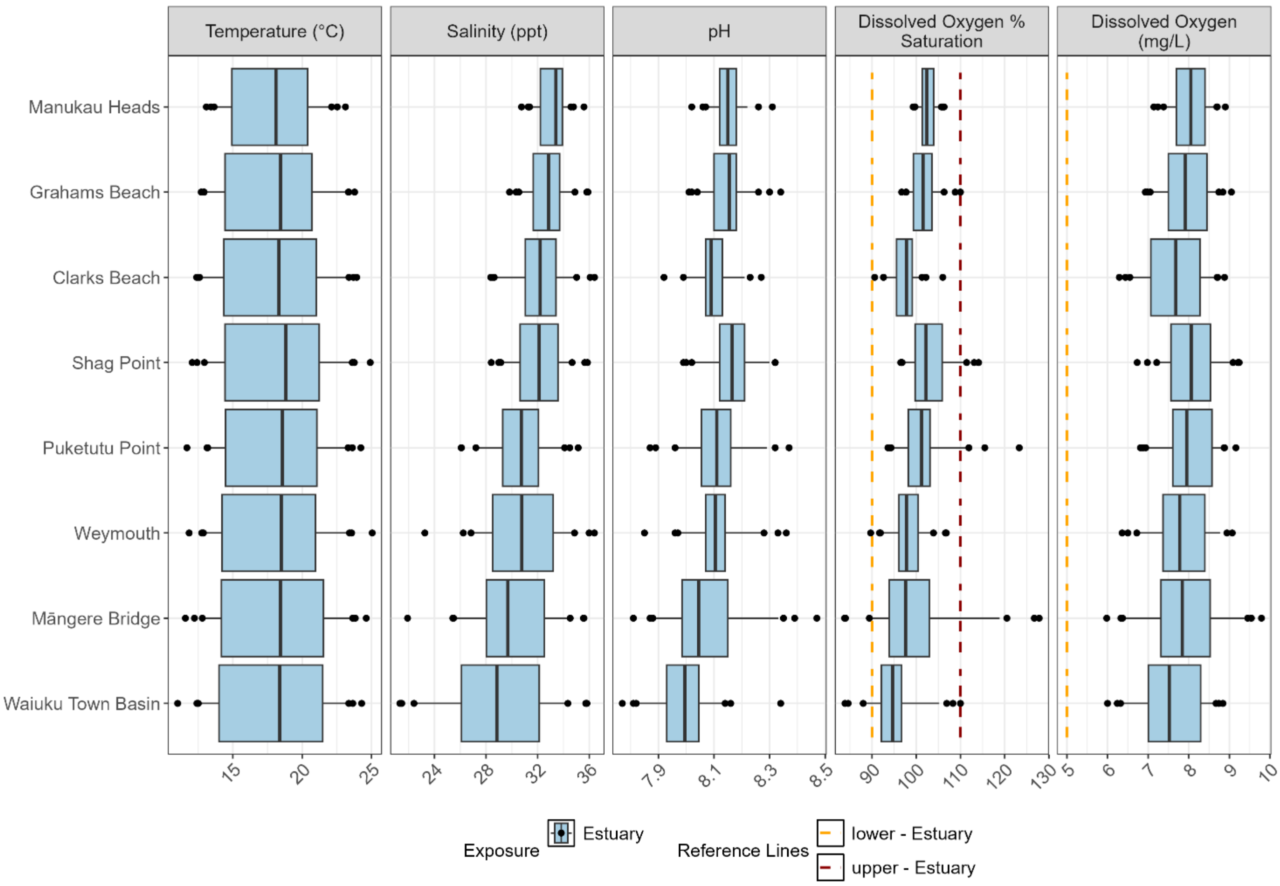

Figure 8-1. Boxplots showing physical parameters at Manukau Harbour monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2.

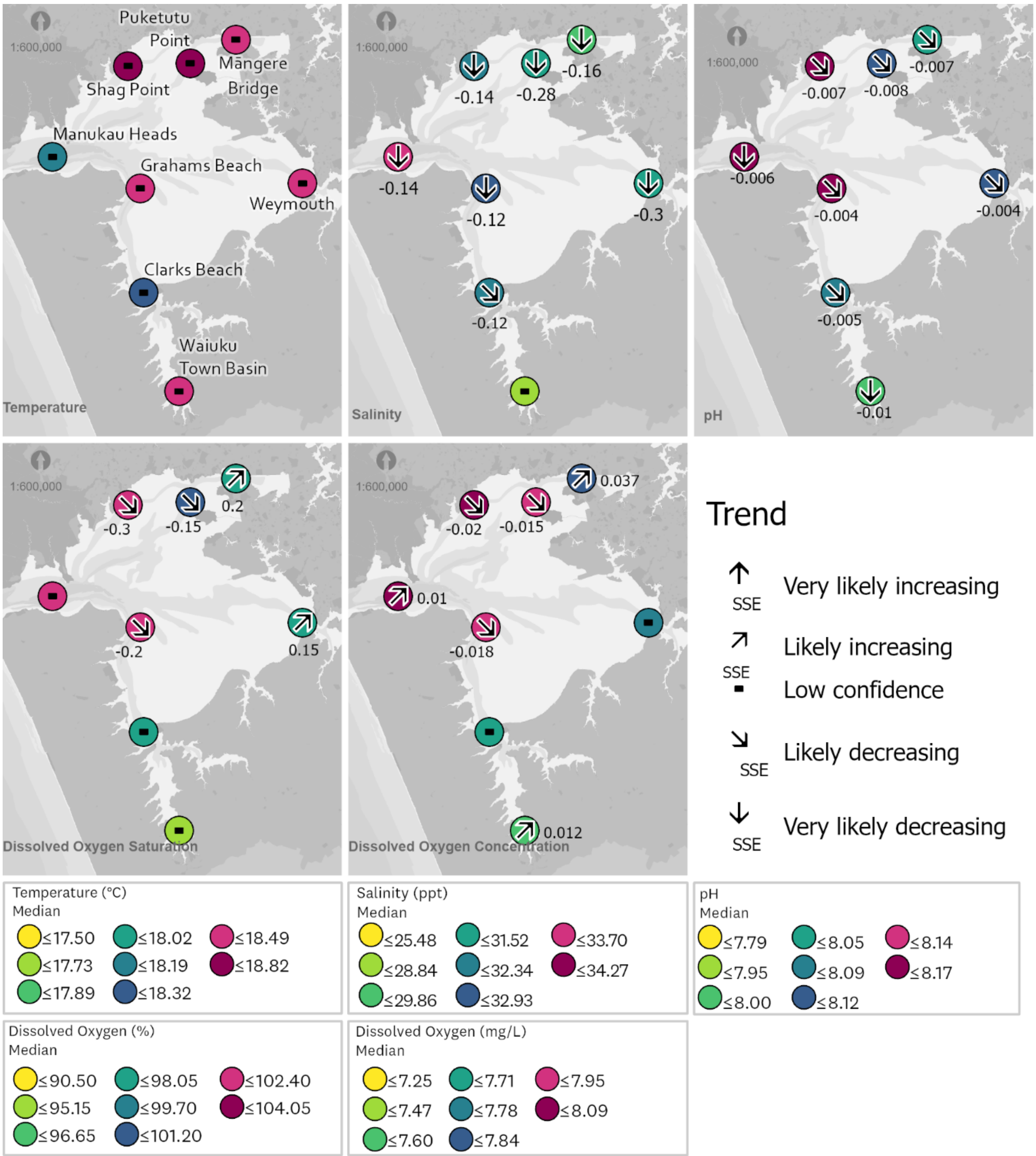

Figure 8-2. Maps showing state (2020 to 2024 median) and 7-year trend (2018 to 2024) information for physical parameters at Manukau Harbour monitoring sites. Units for Sen Slope Estimator (SSE) or annual Sen slope are those of the corresponding parameter.

8.2.2 Nutrients

Nutrient concentrations (both medians and general data range) in the Manukau Harbour were highest at Puketutu Point and Māngere Bridge for all parameters followed by sites in or close to the upper harbour inlets such as Waiuku Town Basin and Weymouth (Figures 8-3 and 8-4). Moving towards the outer harbour nutrient concentrations decreased with the lowest range and lowest medians at Manukau Heads. Five-yearly median values exceeded the guidelines for all nutrient parameters at Waiuku Town Basin, Māngere Bridge, Weymouth, and most strongly at Puketutu Point with exceedances between two and nine times the guideline value (Figure 8-3). At Shag Point and

Clarks Beach total nitrogen guidelines were not exceeded but for all other nutrient parameters median values were either above or close to guideline values. Grahams Beach and Manukau Heads were the only sites without guideline exceedances by nutrient parameter medians. However, in winter and spring monthly median guideline exceedances for ammoniacal nitrogen and total oxidised nitrogen also occurred at these sites (Appendix D Figure D-8).

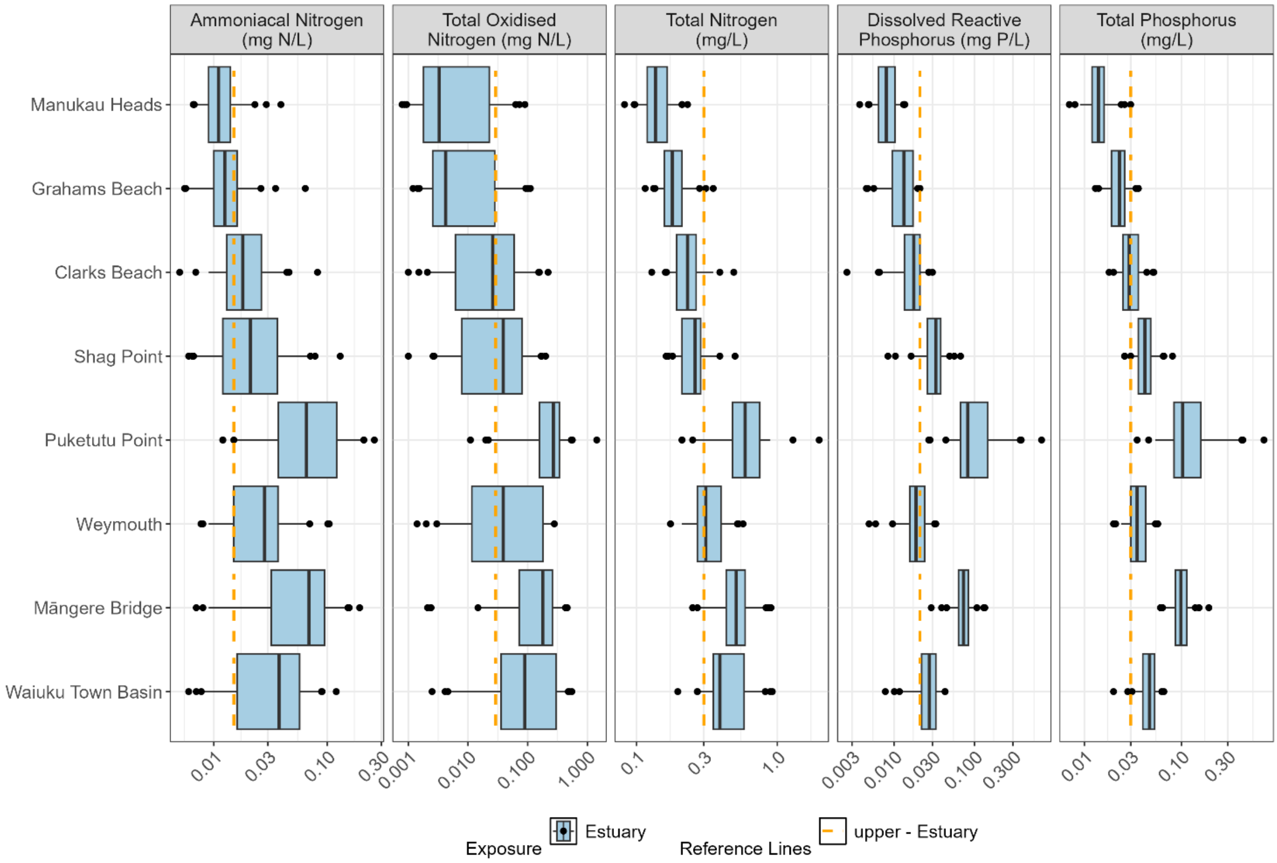

Figure 8-3. Boxplots showing nutrient parameters at Manukau Harbour monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2. The x-axis is shown at log scale.

Seven-year trends for ammoniacal nitrogen and total nitrogen were likely or very likely improving at all sites in the harbour except Puketutu Point where they were likely and very likely degrading. The confidence in trend direction for total oxidised nitrogen was low at many sites across the harbour (Figure 8-4). At Manukau Heads trend direction was likely improving but with censored values affecting the calculation of trend magnitude. Total oxidised nitrogen trends at Puketutu Point, Weymouth and Clarks Beach were very likely or likely degrading. Trends for dissolved reactive phosphorus were improving in the north of the harbour except for Puketutu Point, where the trend was very likely degrading. Likely degrading trends for dissolved reactive phosphorus were also found at Grahams Beach and Clarks Beach in the west of the harbour. At the two upper harbour sites Weymouth and Waiuku Town Basin confidence in trend direction was low (Figure 8-4).

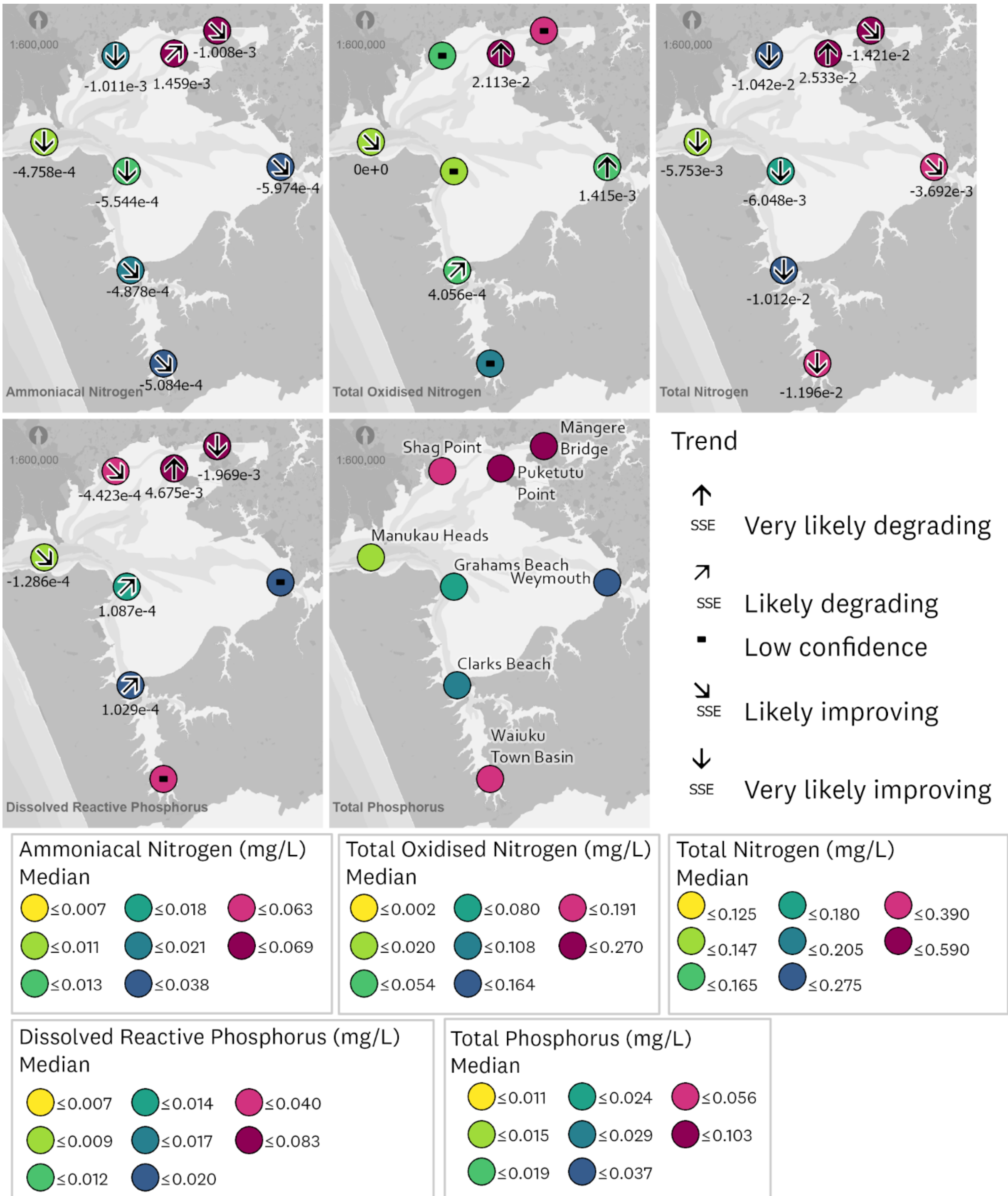

Figure 8-4. Maps showing state (2020 to 2024 median) and 7-year trend (2018 to 2024) information for nutrient parameters at Manukau Harbour monitoring sites. Units for Sen Slope Estimator (SSE) or annual Sen slope are those of the corresponding parameter.

8.2.3 Water clarity

Water clarity parameters showed a spatial gradient across the Manukau Harbour with the lowest median values for chlorophyll *a*, turbidity and total suspended solids at Manukau Heads and values increased moving towards the central harbour and upper harbour inlets (Figures 8-5 and 8-6). The highest median concentrations for all three water clarity parameters were found at Māngere Bridge. Five yearly median chlorophyll *a* concentrations exceeded the guideline value for estuaries at

Weymouth and Māngere Bridge. All other sites showed monthly chlorophyll *a* exceedances mainly from spring to later summer including exceedances of the 90th percentile guideline at Māngere Bride, Waiuku Town Basin, and Weymouth (Appendix D, Figure D-9). Seven-year chlorophyll *a* trends showed improvements at most sites in the Manukau Harbour but the magnitude of trends was low (Figure 8-6). At Manukau Heads and Waiuku Town Basin likely increasing chlorophyll *a* trends were observed also at low magnitudes. Monthly guideline exceedances for turbidity were observed frequently at Māngere Bridge (October to February) and for some months (November and December) at Clarks Beach, Waiuku Town Basin and Weymouth (Appendix D, Figure D-9). Total suspended solids concentrations showed a very similar spatial distribution to turbidity in the Manukau Harbour. Trends for both parameters were very likely improving at most sites (Figure 8-6).

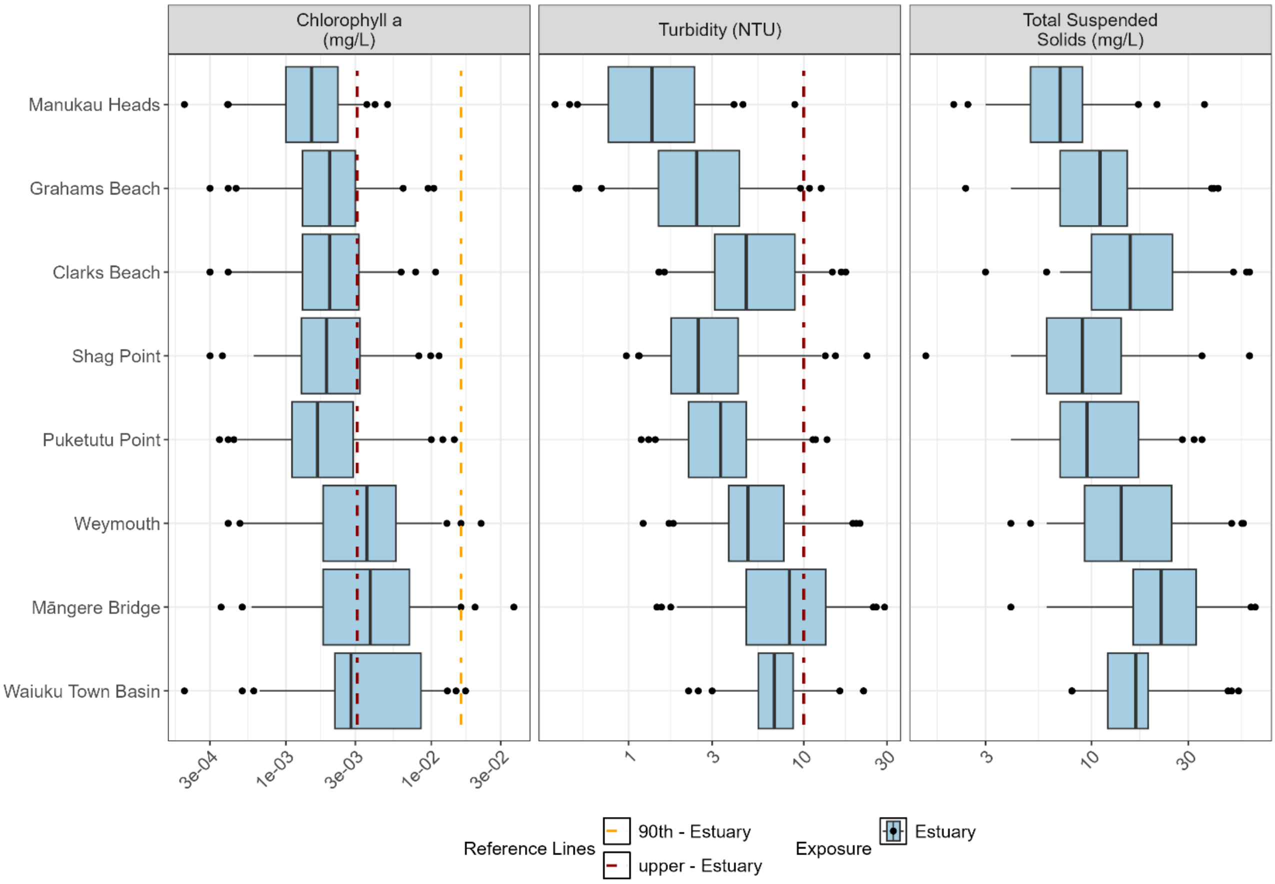

Figure 8-5. Boxplots showing water clarity parameters at Manukau Harbour monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2. The x-axis is shown at log scale.

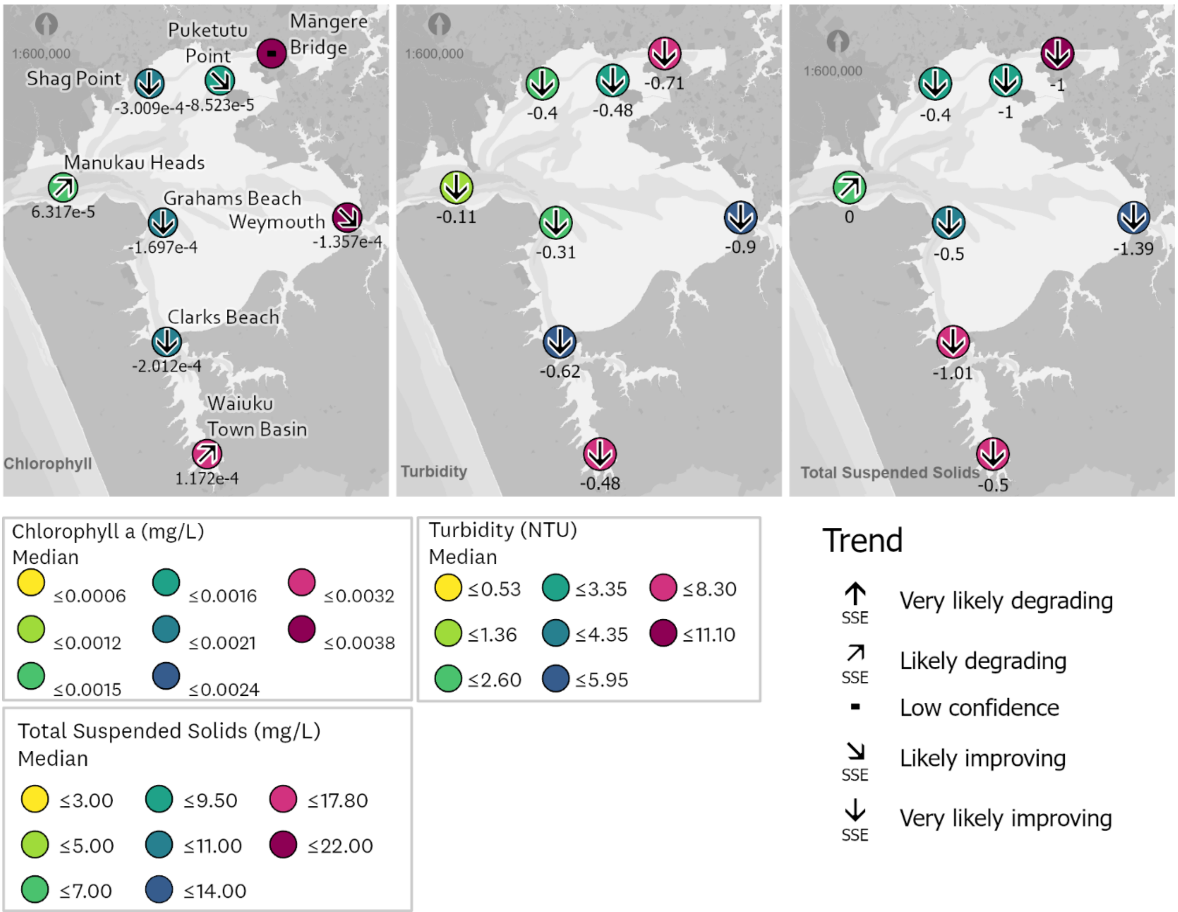

Figure 8-6. Maps showing state (2020 to 2024 median) and 7-year trend (2018 to 2024) information for water clarity parameters at Manukau Harbour monitoring sites. Units for Sen Slope Estimator (SSE) or annual Sen slope are those of the corresponding parameter.

Several sites in the Manukau Harbour showed related dynamics between various water quality parameters over time. An example for Māngere Bridge is shown in Figure 8-7 below. Rising temperatures occurred simultaneously with increases in chlorophyll *a* and drops in total oxidised nitrogen. During peak chlorophyll *a* concentrations, increases in dissolved oxygen saturation at times to levels above 110 per cent were observed and decreased shortly after. Increases in pH also occurred during peak chlorophyll *a* concentrations which fell at the same time as dissolved oxygen saturation.

This pattern was observed at several sites in the harbour and most strongly at sites located towards the inner harbour, such as Weymouth and Waiuku Town Basin and Māngere Bridge.

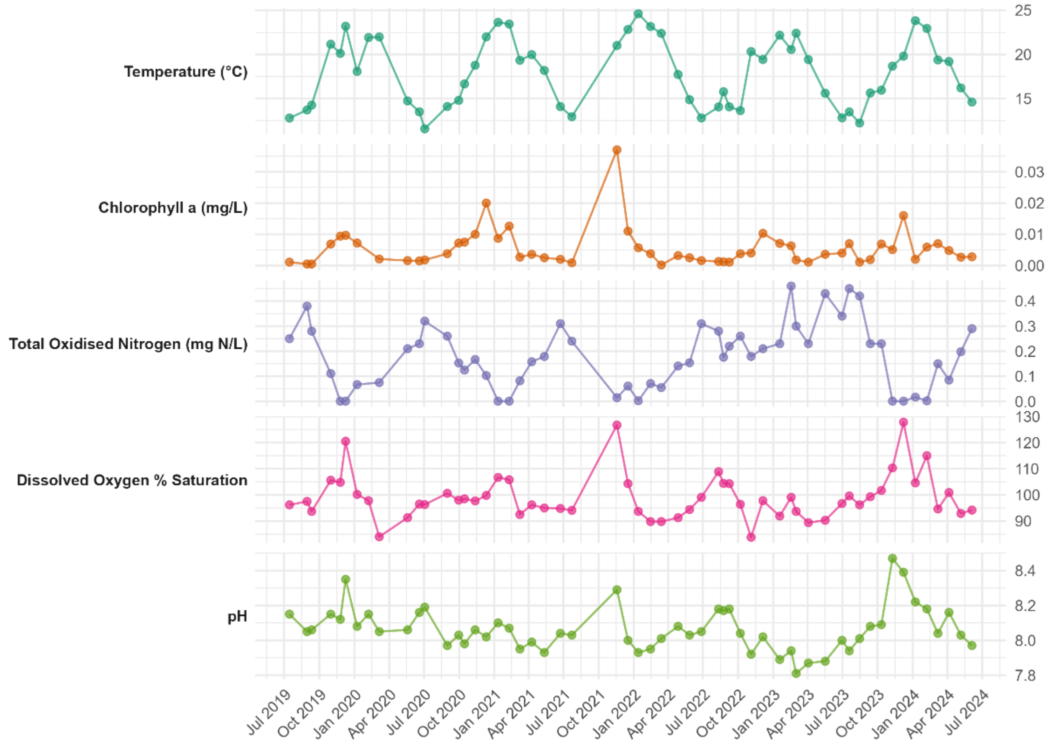

Figure 8-7. Water quality time series for the 2020 to 2024 reporting period at Māngere Bridge.

8.3 Discussion

Significant improvements in water quality in the Manukau Harbour were made since the early 2000s due to upgrades of the Māngere wastewater treatment plant (Auckland Council, 2021). While nutrient concentrations and water clarity parameters remain at these improved levels, signs of pressures on water quality were still observed in the current reporting period. Frequent and high exceedances of nutrient guideline values were recorded in the Manukau Harbour. Spatial patterns showed particularly high nutrient concentrations and strong exceedances at Puketutu Point and towards the inner harbour where land use effects are highest and the dilution from seawater (salinity) is lowest such as Weymouth, Waiuku Town Basin, and Māngere Bridge. Nutrient modelling for total nitrogen and total phosphorus identified the same areas as most impacted in the harbour (Dudley et al., 2024). The strongest phytoplankton blooms with highest and most frequent chlorophyll *a* guideline exceedances were also observed at the inner harbour sites. This included some monthly guideline exceedances of the 90th percentile guideline. The exceedance of this guideline indicates the difference between a fair and poor state based on phytoplankton biomass which is interpreted as a higher risk for a shift in ecological communities to a permanently degraded state (Stevens et al., 2024). This guideline applies to annual rather than monthly statistics, but its exceedance can be interpreted as a conservative indicator of some adverse effects in the harbour.

Phytoplankton appeared to drive dynamics in other water quality parameters in the Manukau Harbour. Increased chlorophyll *a* concentrations (phytoplankton blooms) occurred when water temperature increased and were likely fuelled by inorganic nitrogen in the water column. During or shortly after phytoplankton blooms, total oxidised nitrogen concentrations decreased and at times became depleted. The same seasonal pattern was observed by Gadd et al. (2020) in the nutrient enriched estuary of the Heathcote and Avon rivers. In the Manukau Harbour, dissolved oxygen became at times supersaturated (≥110 per cent) due to the increased photosynthetic activity during the bloom and fell to a seasonal low shortly after, when the organic matter produced during the bloom was consumed or decomposed. Accelerated phytoplankton growth and consequent oxygen supersaturation have been associated with marine heatwaves (Giomi et al., 2019). A prolonged marine heatwave was recorded in New Zealand from November 2021 to November 2022 (NIWA, 2022) the same period some of the above-described nutrient-chlorophyll-oxygen dynamics were observed. It is possible that elevated nutrient concentrations and the occurrence of a strong marine heatwave caused peak phytoplankton growth and oxygen supersaturation in the Manukau Harbour. The likelihood for more frequent and long-lasting marine heatwaves is high especially for the North Island of New Zealand (Cook et al., 2025). The Manukau Harbour may become more susceptible to effects of nutrient enrichment with increased water temperatures and marine heatwave occurrences. Cook et al. (2025) considered high dissolved oxygen saturation to be a likely short-term effect of marine heatwaves and longer lasting events resulting in decreased dissolved oxygen concentration due to breakdown of increased organic matter. Future temperature conditions may therefore result in increased nutrient/oxygen stress in the Manukau Harbour even if nutrient loads remain at current levels.

Increased photosynthesis and consumption of organic matter appeared to also drive pH at some sites in the Manukau Harbour. During the phytoplankton bloom photosynthesis removed hydrogen ions together with CO_2 from the water column consequently increasing pH. When organic matter (produced during the bloom) was consumed heterotrophic activity increased the consumption of oxygen and the release of CO_2 together with hydrogen ions which led to a decrease in pH (Law et al., 2017). This process has been well described for the Firth of Thames where nutrient enrichment led to hypoxic (low oxygen) bottom waters and accelerated acidification (decrease in pH) (Zeldis et al., 2022). In the Manukau Harbour, this pattern was strongest towards the inner harbour, but it was also observed to varying degrees across other monitoring sites. The above-described dynamics between nutrients, chlorophyll *a*, dissolved oxygen and pH occur naturally but the extent of nutrient and chlorophyll *a* guideline exceedances, the occurrence of dissolved oxygen supersaturation and the impact on pH to observable levels were unique to Manukau Harbour sites in the Auckland region. This indicates increased nutrient pressure in the Manukau Harbour with the potential to negatively impact its ecological health. Further investigation into the frequency, duration and spatial distribution of phytoplankton blooms and related dissolved oxygen and pH dynamics are needed to gain a better understanding of the ecological impact of nutrient enrichment in the Manukau Harbour.

Trend results indicated that there was improvement at most sites in the harbour for nutrients and chlorophyll *a*. However, trend magnitudes were low indicating a slow rate of change, consistent with findings from previous reports (Ingley, 2021). Reductions of nutrient loads would likely be required to accelerate improvement of water quality in the Manukau Harbour. Additionally, some degrading trends were also observed, most notably at Puketutu Point where all nutrient trends were very likely or likely degrading. This is a change in trends from the last state and trends report (Ingley, 2021) when nutrient trends were either of low confidence or improving. The site is close to the discharge for New Zealand's largest wastewater treatment plant in Māngere. The seven-year trend period was affected by heavy rain events which have the potential to increase nutrient concentrations and affect operations at the treatment plant. Since February/March 2023 nutrient concentrations at Puketutu Point increased and strong peak concentration for all nutrient parameters were observed in August 2023, February and March 2024. Until June 2023 no increase in discharge load from the Māngere wastewater treatment plant was observed (Kelly, 2023). However, in the 2023 hydrological year bypass events increased in number of events, duration and total volume to the highest in a decade due to the storm events (Kelly, 2023). These bypass events may have contributed to increased nutrient concentrations at Puketutu Point. Further investigation of the effects of bypass events on harbour water quality should be undertaken including if these peaks in nutrient concentrations observed in the 2024 hydrological year coincide with bypass events. Storm events with high rainfalls are expected to become more frequent and stronger under climate change predictions (Macara et al., 2024) Therefore, understanding the effects of bypass events on the harbour will be important for future management.

Total suspended solid concentrations and turbidity showed very similar spatial patterns to chlorophyll *a* across the Manukau Harbour, with highest concentrations and the most turbid waters in the upper harbour areas close to freshwater inflows at Māngere Bridge, Weymouth, and Waiuku Town Basin. Previous reporting showed correlation between these parameters (Kelly and Kamke, 2023). It is therefore likely that chlorophyll *a* drives both turbidity and total suspended solids to some extent in the Manukau Harbour. The highest sediment loads into the Manukau Harbour were predicted to originate from the Pahurehure inlet and Puhinui Creek (Dudley et al., 2024) which would impact the Weymouth monitoring sites most strongly. There was no strong difference between water clarity parameters at Weymouth and other upper harbour sites. The distribution of suspended sediment in the water column is difficult to determine with current data but future reporting will provide information on organic and inorganic fractions of suspended solids, as volatile suspended solids have been added to the monitoring programme in 2023. Regardless trends showed improvement across the harbour at comparatively higher magnitudes for total suspended solids and turbidity than chlorophyll *a* which might indicate improvement in the concentrations of inorganic material in the water column.

9 Kaipara Harbour

9.1 Background

Kaipara Harbour is the largest estuary in Aotearoa / New Zealand and among the largest in the Southern Hemisphere. Approximately half of its 743 km² area lies within Auckland Council's jurisdiction (southern Kaipara Harbour) and is part of a 1,409 km² catchment, 24 per cent of which is in the Auckland region. The southern harbour catchment includes 31 smaller stream catchments draining about 5,480 km of permanent streams. The majority of freshwater entering the harbour comes from the Wairoa River in Northland, which drains a significantly larger catchment than rivers in the Auckland region (Reeve et al., 2009).

The southern Kaipara catchment land cover is predominantly rural, characterised by extensive areas of high-producing exotic grassland and notable expanses of exotic forest (Auckland Council, 2025). Approximately 13 per cent of the catchment has been identified as highly erodible land (Green and Daigneault, 2018) and sediment loading is a primary concern for the harbour. Cropland is present near Te Ngaio Point, while the most prominent urban area is centred around Helensville at the upper end of the Kaipara River. Since the last reporting period, numerous small-scale land use changes have occurred across the catchment. The most frequent change was due to forest harvesting. Outside of forest harvesting, land use changes made up about three per cent of the total harbour catchment and were mostly conversion from high-producing exotic grassland to either indigenous scrub/shrubland, cropland, exotic shrubland, indigenous forest and urban areas.

9.2 State and Trend Results

9.2.1 Physical parameters

Median water temperatures in the Kaipara Harbour ranged from approximately 18°C to 19°C with the narrowest temperature range (13°C to 22°C) at Kaipara Heads and slightly wider ranges at all other monitoring sites (12°C to 24°C) (Figures 9-1 and 9-2). Trend results for water temperature showed low confidence in trend direction at all but the two outer harbour sites Tauhoa Channel and Kaipara Heads where seven-year trends were likely increasing (Figure 9-2). Over a 15-year trend period water temperature trends across the harbour were likely or very likely increasing by 0.01 to 0.07°C per year. As expected, median salinity concentrations changed with distance from freshwater sources, moving up the harbour from Kaipara Heads (median 34 ppt) to 30 ppt at Kaipara River Mouth and Hōteo River Mouth. These sites in the inner harbour experienced a broad range in salinity from 12 ppt to 36 ppt (Figure 9-1). Spatial patterns of pH were similar to those of salinity. Trends for both salinity and pH were likely to very likely decreasing across the harbour over seven-year periods. This was confirmed in 15-year trends for salinity, but pH trends were very likely increasing for all sites over the longer trend period which was consistent with regional results (see Section 3).

Across the harbour there was a distinct gradient of dissolved oxygen saturation and concentration with the lowest median values and wider data range at Kaipara River Mouth and Makarau Estuary, and the highest median values and narrow data range at Kaipara Heads (Figures 9-1 and 9-2). Guideline exceedances of median dissolved oxygen were not observed but at Kaipara River Mouth and Makarau Estuary lower percentile values were below the 90% dissolved oxygen saturation guideline. Seven-year dissolved oxygen trends were likely to very likely increasing for most sites (Figure 9-2) but as shown in Section 3 turned to likely or very likely decreasing trends when the trend period was extended to 15 years. Magnitudes of oxygen trends were low regardless of the trend period (Figure 9-2 and Appendix C, Supplementary data file 2).

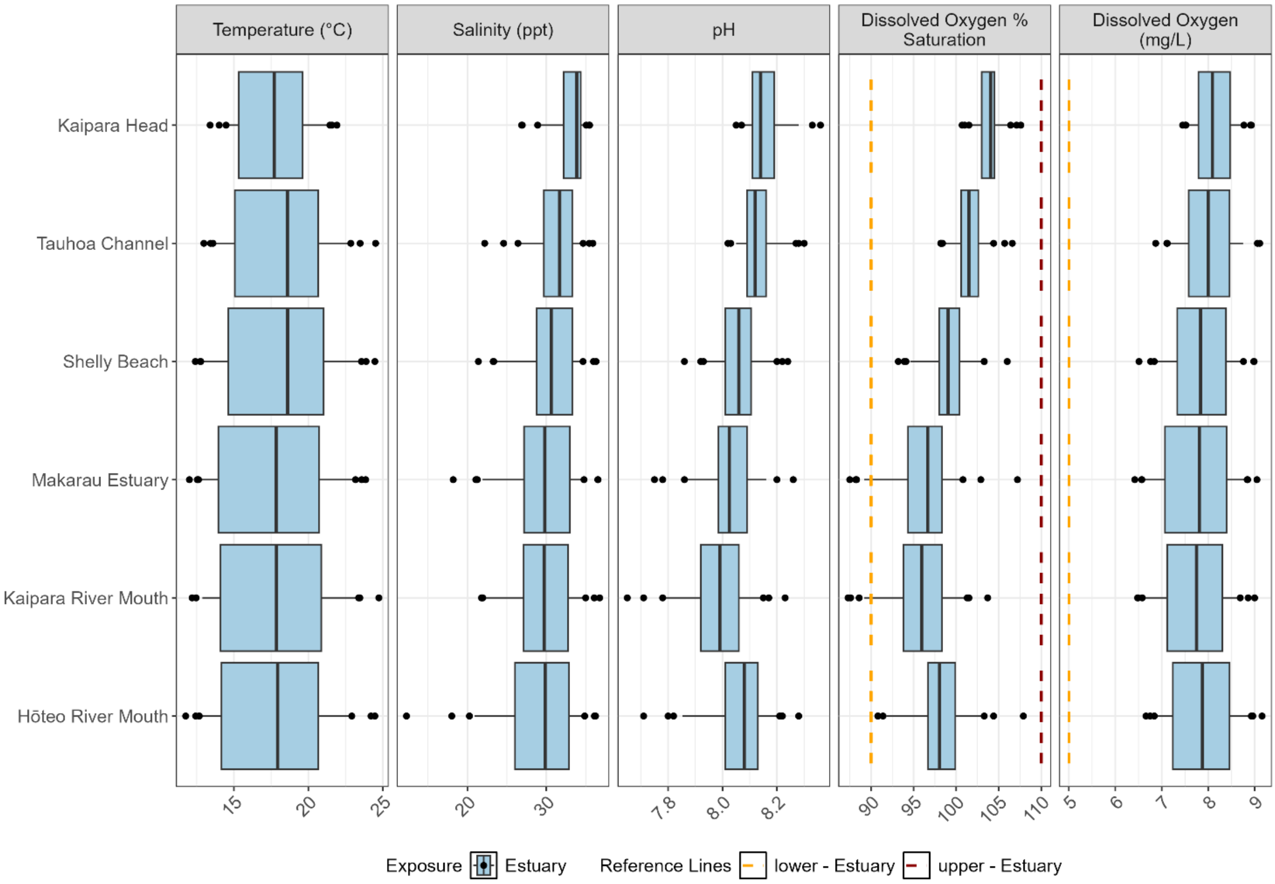

Figure 9-1. Boxplots showing physical parameters at Kaipara Harbour monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2.

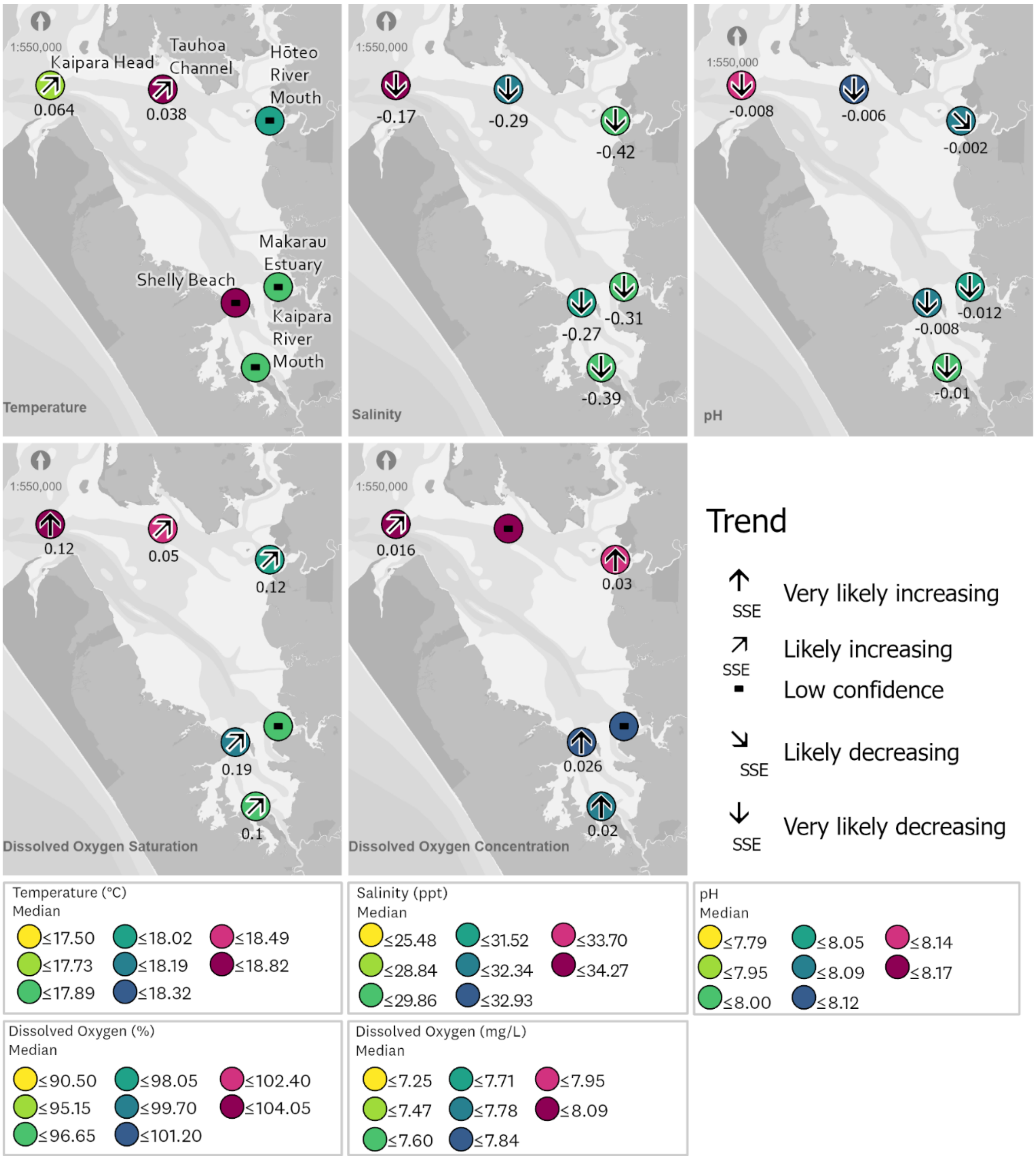

Figure 9-2. Maps showing state (2020 to 2024 median) and seven-year trend (2018 to 2024) information for physical parameters at Kaipara Harbour monitoring sites. Units for Sen Slope Estimator (SSE) or annual Sen slope are those of the corresponding parameter.

9.2.2 Nutrients

Nutrient concentrations were generally lower at the two outer harbour sites, Tauhoa Channel and Kaipara Head and higher at the inner harbour sites with highest median concentrations at Kaipara River Mouth (Figures 9-3 and 9-4). Guideline values for ammoniacal nitrogen were exceeded in five-yearly medians at all inner harbour sites and at Kaipara River Mouth for total nitrogen and total phosphorus (Figure 9-3). Seasonal elevation in total oxidised nitrogen was observed at all sites leading to monthly guideline exceedances in winter at all sites except Kaipara Head. The strongest exceedances were observed at Kaipara and Hōteo River Mouths (Appendix D, Figure D-10). Concentrations for both ammoniacal nitrogen and total oxidised nitrogen were elevated in winter. At

Hōteo River Mouth, monthly medians in June and July also exceeded the total nitrogen guideline. Trend analysis showed that nutrient concentrations were improving across the Kaipara Harbour with likely and very likely improving trends across most sites and parameters (Figure 9-4). The confidence in the trend direction for total oxidised nitrogen was low at many sites or the trend magnitude could not be determined due to a high proportion of censored values. The only degrading trends for nutrient parameters were found for ammoniacal nitrogen at Kaipara River Mouth and Makarau Estuary (Figure 9-4).

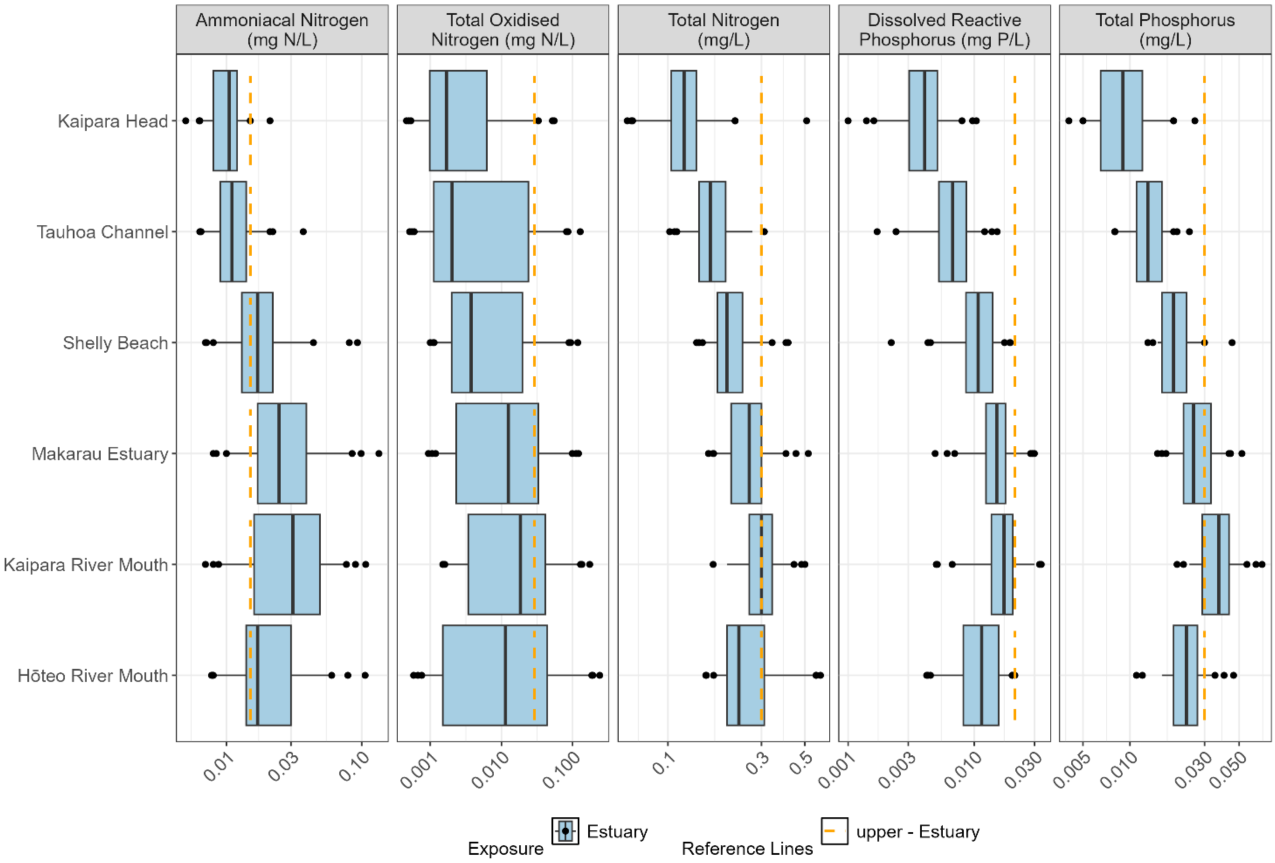

Figure 9-3. Boxplots showing nutrient parameters at Kaipara Harbour monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2. The x-axis is shown at log scale.

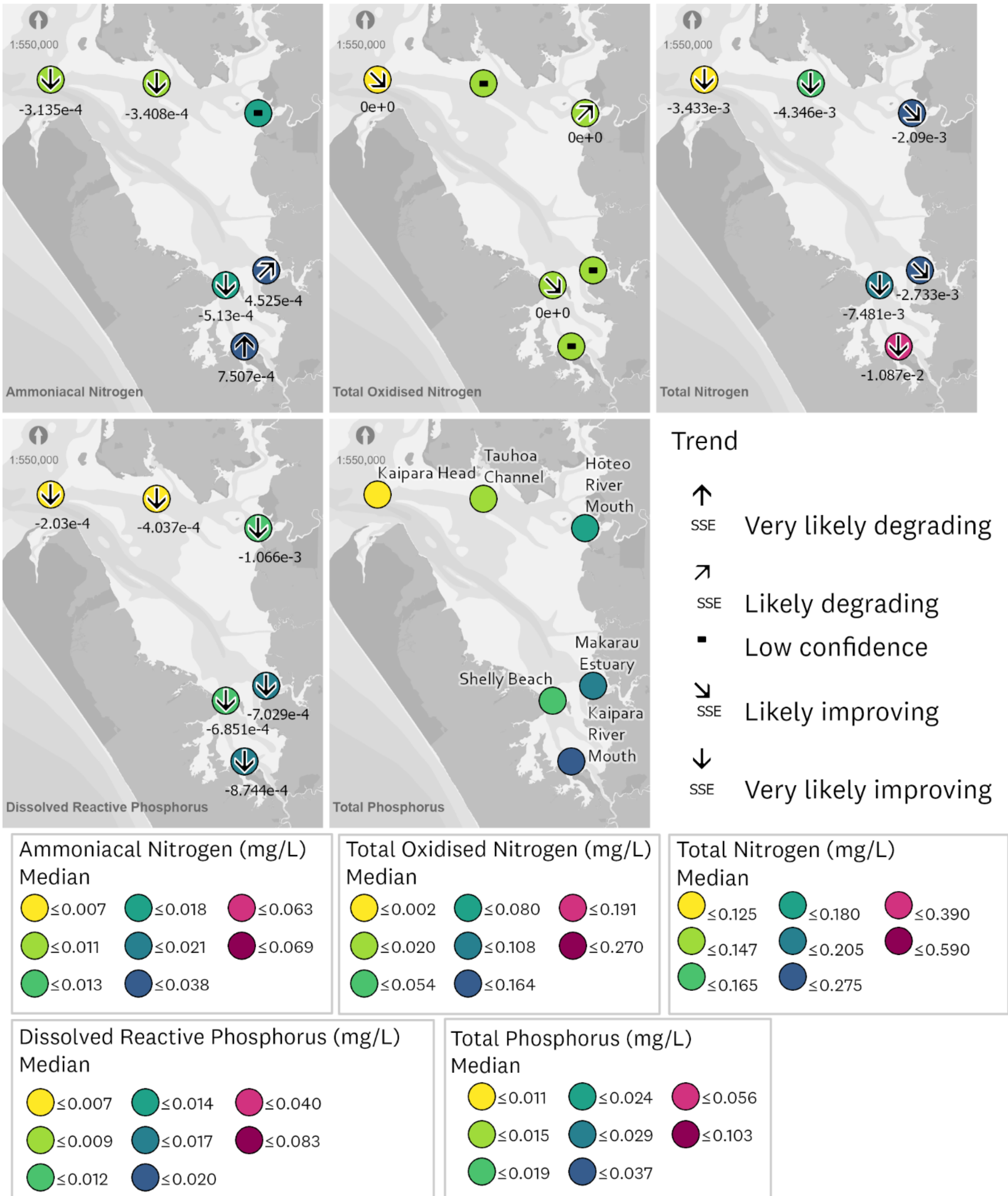

Figure 9-4. Maps showing state (2020 to 2024 median) and seven-year trend (2018 to 2024) information for nutrient parameters at Kaipara Harbour monitoring sites. Units for Sen Slope Estimator (SSE) or annual Sen slope are those of the corresponding parameter.

9.2.3 Water clarity

All water clarity parameters showed a strong gradient moving from lowest median concentration in the north of the harbour at Kaipara Heads to highest concentrations in the south at Kaipara River Mouth (Figures 9-5 and 9-6). At Kaipara River Mouth, five-yearly median concentrations exceeded guideline values for chlorophyll *a* and turbidity. Few monthly chlorophyll *a* guideline exceedances were also observed at Hōteo River Mouth, Makarau Estuary, Shelly Beach, and Tauhoa Channel but monthly medians for turbidity remained below guideline levels at these sites (Appendix D, Figure D-11). Trend analysis showed improving trends for water clarity parameters at most sites and with higher rates of improvement at inner harbour sites in the south (Figure 9-6). Kaipara River Mouth and Makarau Estuary showed very likely improving trends for chlorophyll *a* with the highest magnitudes of improvement in the harbour. Moving towards the outer part of the harbour the probability for improving trends becomes less likely and trend magnitudes decreased (Shelly Beach and Hōteo River Mouth). At Tauhoa Channel confidence in chlorophyll *a* trend direction was low and at Kaipara Heads the trend direction was likely degrading (Figure 9-6). Turbidity trends were very likely improving at all sites, as were total suspended solids trends at Shelly Beach and Kaipara River Mouth. Hōteo River Mouth and the northern harbour sites had less clear trend results for total suspended solids with either low confidence in trend direction or trend magnitude estimation affected by censored values.

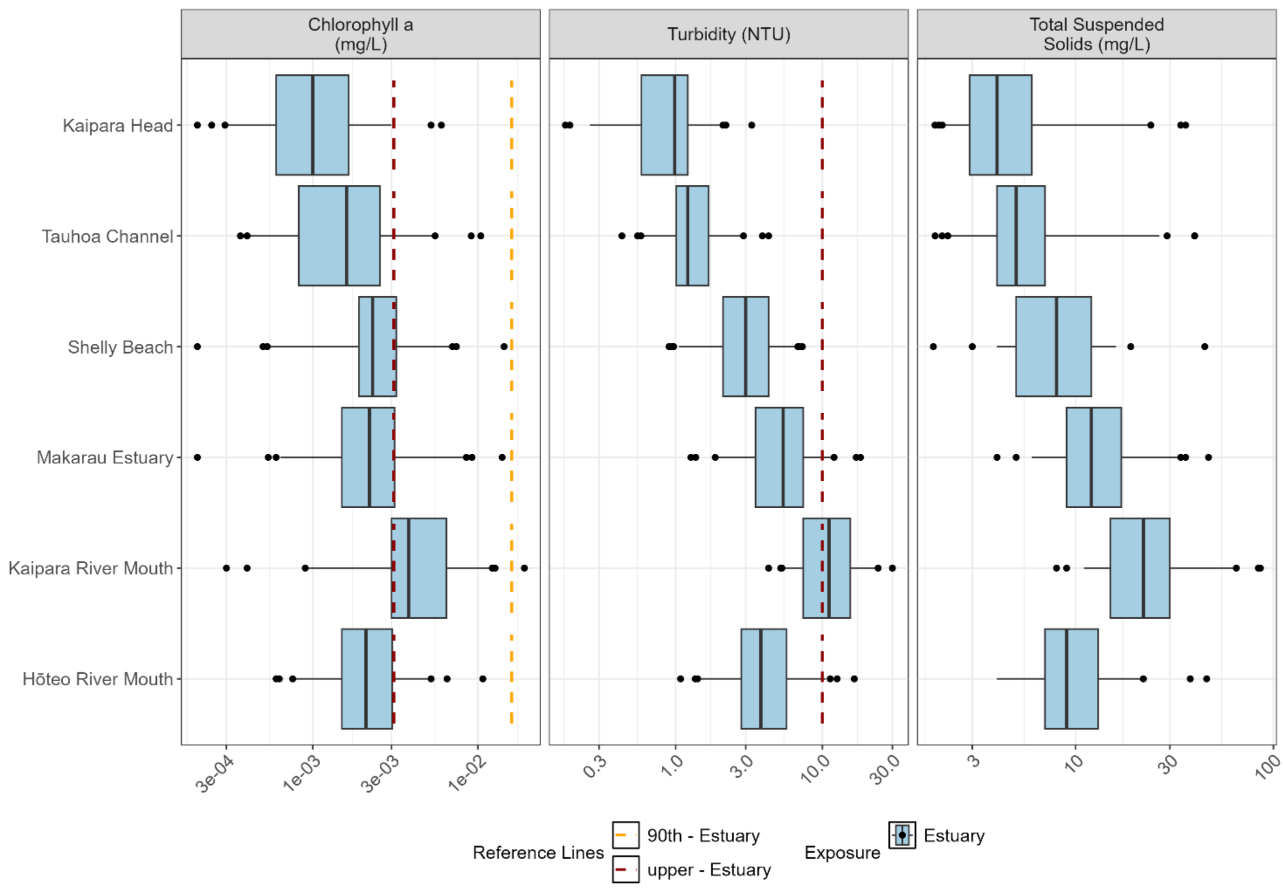

Figure 9-5. Boxplots showing water clarity parameters at Kaipara Harbour monitoring sites for the 2020-2024 reporting period. Centre line denotes the median, box borders denote the 25th and 75th percentiles, whiskers present the 5th and 95th percentiles, dots mark data outside of this range. Reference lines refer to the relevant guidelines in Table 2-2. The x-axis is shown at log scale.

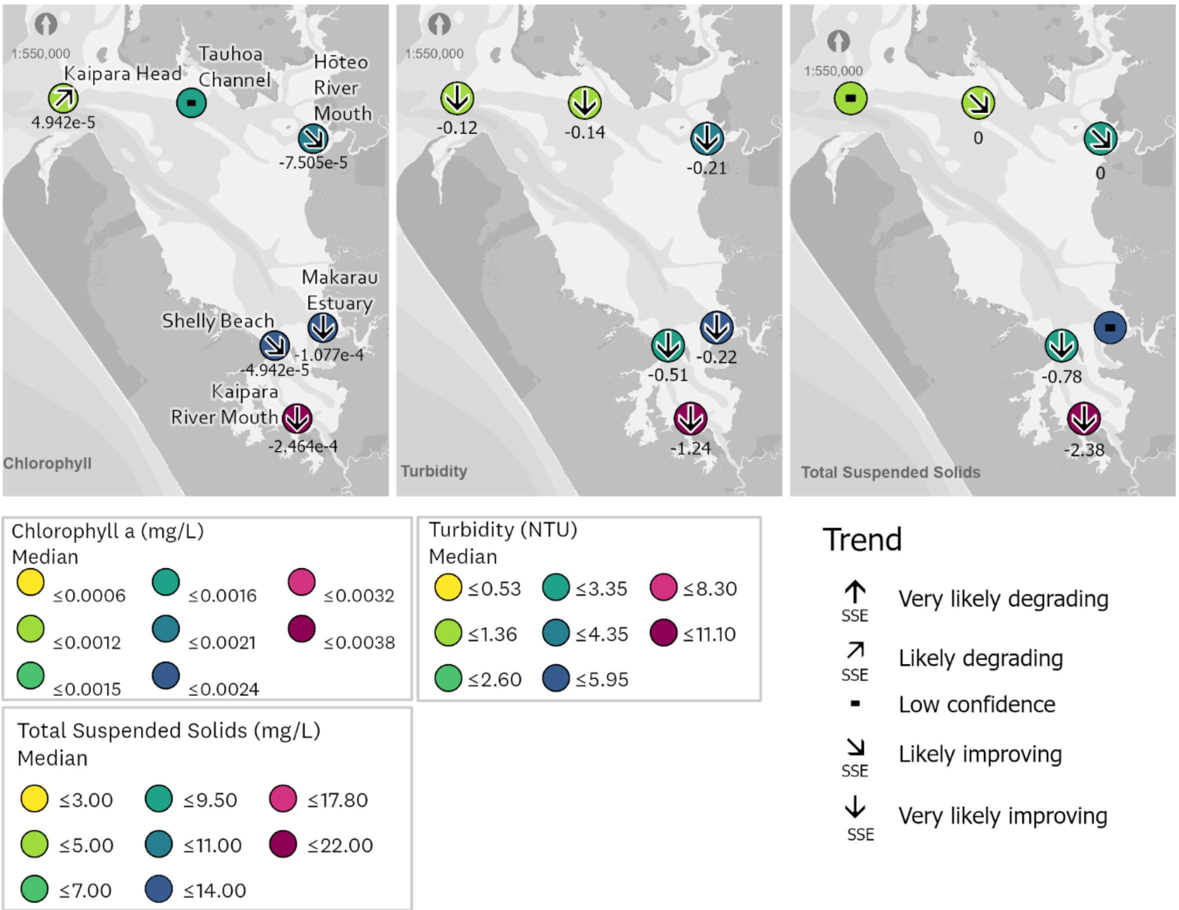

Figure 9-6. Maps showing state (2020 to 2024 median) and seven-year trend (2018 to 2024) information for water clarity parameters at Kaipara Harbour monitoring sites. Units for Sen Slope Estimator (SSE) or annual Sen slope are those of the corresponding parameter.

9.3 Discussion

Physical water quality parameters showed gradients that are expected for the locations of the sampling sites. Upper harbour sites closest to freshwater input such as Kaipara River Mouth, Hōteo River Mouth and Makarau Estuary experienced stronger freshwater impact as shown in the wider salinity and pH range as well as lower median values for these parameters. The differences in pH trend direction observed in the Kaipara Harbour were common for the Auckland region and likely due to increased freshwater impacts due to heavy rain events during the current monitoring period (see Section 3). The extreme weather events towards the end of the seven-year trend period may also have influenced trends for laboratory parameters and trend results should be confirmed once a longer record of consistent monitoring data becomes available. The impact of heavy rainfall events on Kaipara Harbour sampling sites was observed in the form of decreased salinity and increased nitrogen concentrations in February and May 2023 (Kamke, 2025). Despite these events the overall state described in this report was consistent with findings in previous reports (Ingley, 2021; Kelly and Kamke 2023).

Signs of nutrient enrichment were localised in the Kaipara Harbour. While ammoniacal nitrogen concentrations exceeded guidelines at all sites in the inner harbour, only Kaipara River Mouth showed additional signs of nutrient enrichment in the form of guideline exceedances for other nutrient parameters and chlorophyll *a*. At Kaipara River Mouth, spring and summer phytoplankton blooms occurred as indicated by increased chlorophyll *a* concentration but no reduction in dissolved oxygen saturation or concentration below guidelines were observed. However, past reporting mentioned occasional events when the lower dissolved oxygen guideline was breached (Ingley 2021). Signs of eutrophication were also observed in the tidal sections of the Kaipara River (upstream of the Kaipara River Mouth) during synoptical surveys in summer months in 2023/24. Depth profile data revealed a well-mixed water column but decreasing dissolved oxygen concentrations moving into the upper parts of the tidal sections of the Kaipara River with values well below 5 mg/L (Auckland Council, unpublished data). According to the recommended minimum dissolved oxygen concentration guideline a seven day mean minimum concentration below 5 mg/L represents a poor ecological quality status, which is the worst score possible for the proposed indicator (Stevens et al., 2024). This classification indicates "significant stress on aquatic organisms caused by dissolved oxygen less than tolerance levels with a likelihood of local extinction of keystone species and loss of ecological integrity" (Stevens et al., 2024). While this indicator is intended to be applied to continuous monitoring data the authors state that it can be used on discrete data as a conservative measure. Further investigations are required to understand the spatial and temporal extent of nutrient pressures in the tidal sections of the Kaipara River.

Current trend analysis results showed a contrasting picture with degrading trends for ammoniacal nitrogen but improving trends for total nitrogen and chlorophyll *a* at the Kaipara River Mouth monitoring site. Future trend analysis over a longer time period is needed to confirm trend direction and magnitude and consequently to understand if nutrient pressures at Kaipara River Mouth are improving or degrading. There is a risk that with increasing temperatures due to climate change (as shown by increasing 15-year temperature trends) estuarine water will become more susceptible to eutrophication effects. The decreasing trends in dissolved oxygen over a 15-year period could be an early sign of higher eutrophication susceptibility. Based on current results, the Kaipara River and the southern compartment of the Kaipara Harbour (i.e. the area south of Shelly Beach) could benefit from lower nutrient loads to prevent further adverse effects. Modelling results for the Kaipara Harbour have shown that the largest freshwater sources of total nitrogen into the southern compartment are the Kaipara River and Kaukapakapa River which together contribute 26 per cent of total nitrogen (Dudley et al., 2024). Another notable source is the Wairoa River which was estimated to contribute 15 per cent of total nitrogen into the southern compartment. The Wairoa River drains a large rural catchment under the jurisdiction of Northland Regional Council. Load reduction might therefore require catchment interventions in the Auckland region and collaboration with Northland Regional Council.

Like nutrient parameters, effects on water clarity were localised in the Harbour to the Kaipara River Mouth monitoring site. The highest concentrations of total suspended solids, turbidity, and chlorophyll *a* in the harbour were recorded at this monitoring site with frequent guideline exceedances for both chlorophyll *a* and turbidity. Total suspended solid concentrations at this site were the highest in the Auckland region (incl. upper and lower percentiles and median). This indicates highly turbid waters at Kaipara River Mouth and is consistent with previous reporting (Ingley, 2021; Kelly and Kamke, 2023) and increasing mud content at the nearby marine ecology monitoring site (Drylie, 2025). Our current SOE monitoring cannot differentiate between organic and inorganic components of total suspended solids, therefore the proportion of sediment is unknown. Future reporting will provide more details as volatile suspended solids which present the organic fraction of total suspended solids were included in the monitoring programme in 2023.

Modelling by Dudley et al. (2024) showed that the largest source of sediment in the harbour area south of Shelly Beach is the collective load of the Kaipara and Kaukapakapa Rivers (approximately 21,749 t per year). Despite higher sediment load estimations for the Hōteo River (with 44,352 t per year, the second largest source for the Kaipara Harbour) (Dudley et al., 2024) our monitoring did not indicate high turbidity or total suspended solid concentrations at Hōteo River Mouth. Previous reporting also did not find indications for high concentrations of suspended sediment or high turbidity at this site (Ingley and Groom, 2022). The highest sediment loads into estuaries occur during heavy rain events (Green et al., 2021) which are not directly captured in our SOE monitoring. However, the impacts of Cyclone Garbielle were observed in February 2023 monitoring in the Kaipara Harbour and while turbidity for this month (16.5 NTU) was the maximum value in the current reporting period at Hōteo River Mouth, this was in the range of the 75th percentile for the Kaipara River Mouth (15.5 NTU)[4]. It is possible that sediment at Hōteo River Mouth is flushed rapidly and therefore not picked up in our monitoring but resuspension of sediment at the Kaipara River Mouth site might also contribute to the high turbidity and total suspended solid concentrations. Direct monitoring during storm events is not possible for our SOE programme. It is therefore likely that the strongest sediment impacts on the Kaipara Harbour were missed. Event-based monitoring using high frequency methods would be more suitable to investigate sediment impacts on the Kaipara Harbour and other estuaries in the region. Such monitoring takes place in rural freshwater sites in the Auckland region (Tsyplenkov and Neverman, 2025) but does not include loading into estuaries.

Trend results indicated improvement in water clarity parameters at many sites in the Kaipara Harbour. Kaipara River Mouth, the monitoring site with lowest water clarity in state results showed the highest levels of improvement. Trend magnitudes for turbidity and total suspended solids indicated high levels of improvement of more than 1 NTU and more than 2 mg/L per year, respectively. Previous reporting also showed improving trends for turbidity with highest rate of improvement at Kaipara River Mouth (Ingley, 2021). This report confirms this trend direction and shows three times higher improvement for turbidity compared to the last state and trends report. If trend results from the current reporting period can be confirmed with data from longer trend periods, the levels of improvement at Kaipara River Mouth should result in better state statistics for this site within the next few years.

Reducing sediment loads into the Kaipara Harbour is a priority of the Kaipara Moana Remediation programme which includes catchment interventions such as wetland restoration, stream fencing and planting on eroding land. Several smaller conversions of exotic grassland to native forest or indigenous shrubland were seen in the latest update of land cover for the Kaipara Harbour

[4] February 2023 laboratory samples for Kaipara River Mouth were of poor quality and excluded from analysis due to late arrival at laboratory.

catchments. Such interventions have the potential to improve water quality in the Kaipara Harbour further in the future.

10 Summary

This report provides an update on coastal and estuarine water quality state and trends up to June 2024 in Tāmaki Makarau / Auckland.

Data analysis was influenced by step-changes for some nutrient and water clarity parameters following changes in laboratory methods in 2015, 2017, and 2020 (Table 2-2). State results spanning these periods should be compared with caution as results for some parameters were systematically higher or lower after the change. This can be misinterpreted as improvement or degradation. In addition, guideline values based on data before step changes may be more stringent or lenient when compared to current data. For future reporting, the locally derived guideline values and the WQI should be reviewed with consistent monitoring data.

Due to the step changes, trend assessments for most parameters were limited to a seven-year period (July 2017-June 2024). For parameters measured in the field (and not affected by changes in methods), additional analyses covered 10- and 15-year periods. Comparisons across trend periods revealed the influence of frequent heavy rain events from late 2022 to early 2024, which particularly affected the seven-year trends. These shorter trends showed greater sensitivity to climatic variability, with trend directions for pH and water temperature shifting from decreasing over seven years to increasing over 10 and 15 years. Dissolved oxygen trends changed from increasing to decreasing at most sites. Salinity consistently decreased across all trend periods, though the rate of decrease was slower in the longer records. It is likely that nutrient and water clarity trends were similarly affected by recent weather events. We therefore recommend confirming the trend results reported here once a longer, more consistent data record is available; in the meantime, the seven-year trend results should be treated as indicative.

State analysis using the coastal water quality index showed that sites on the open coast and outer estuary, with greater marine influence, generally had the highest water quality, rated as “good” or “excellent”. Water quality impacts from nutrients and reduced clarity became more pronounced at sheltered estuarine sites with stronger freshwater influence, where conditions were largely rated as “fair”. The most impacted sites often rated “marginal” or “poor”, were those closest to freshwater sources in the upper estuaries. Overall, water quality classifications either improved or remained consistent with previous reporting periods.

Regionwide signs of improvement were also seen in trend analysis. More than 75 per cent of sites showed improving trends for total nitrogen, dissolved reactive phosphorus and turbidity. Ammoniacal nitrogen and total suspended solid trends were improving at more than 70 per cent of sites. Improving trends for chlorophyll *a* were found at more than half of all sites.

Individual assessments of water quality across six reporting areas, including the region’s three major harbours, reflected these broader regional patterns but also revealed localised impacts on water quality. Encouragingly, monitoring sites along the Hauraki Gulf coastline, including Mahurangi Harbour and open coast sites at the East Coast, as well as the Wairoa River Mouth showed few signs of reduced water quality. Guideline exceedances for nutrient and water clarity parameters were few and trends were generally improving.

Water quality results for the Waitematā Harbour provided a mixed picture. Water quality at Chelsea, the outermost site, was overall good and most trends were improving. Central Harbour monitoring sites at Whau Creek, Hobsonville and Henderson showed signs of reduced water clarity with some degrading trends. These could be related to sediment impacts from the catchment but also resuspension of sediments. At the upper harbour tidal creek sites guidelines exceedances and degrading trends for nitrogen parameters indicated nutrient pressures. Elevated nitrogen may have fuelled phytoplankton blooms and consequently high dissolved oxygen consumption as seen by some chlorophyll *a* guideline exceedances, and degrading trends for chlorophyll *a* and dissolved oxygen. The observed increased freshwater influence towards the end of the reporting period as well as land cover changes may have influenced water quality at these sites but it was not possible to directly identify the cause of the observed changes. Further investigations may be beneficial to understand the relevant drivers of changing water quality at these sites.

Water quality in the Tāmaki Estuary appeared to be improving at both sites but showed differences between them. Trends were improving for most parameters and guideline exceedances were few. The monitoring site at Panmure showed slightly higher nutrient concentrations and more turbid waters due to higher freshwater influence compared to the Tāmaki monitoring site. Nutrient pressures and low dissolved oxygen concentrations in the upper arms of the estuary were indicated by other studies but were not detected at our monitoring sites. To capture a complete picture of water quality in the Tāmaki Estuary targeted investigations for signs of nutrient enrichment in the upper parts of the estuary should be considered.

Water quality in the Manukau Harbour showed signs of nutrients impacts with frequent water quality guideline exceedances across most sites but most prominently at sites close to freshwater inputs in the upper arms of the harbour and close to the discharge of the Māngere Wastewater treatment plant at Puketutu Point. While improvements in water quality were observed at many sites in the harbour these were at low rates and degrading trends at Puketutu Point were observed. Guideline exceedances and degrading trends at Puketutu Point may be related to heavy-rain events and are worth further investigation. At some sites, signs of nutrient and temperature driven phytoplankton dynamics affecting water pH and dissolved oxygen were detected. These dynamics may have been caused by a combination of high nutrient concentrations and prolonged marine heat waves during the reporting period. Targeted monitoring to better understand these dynamics would be beneficial to inform management of the harbour.

In the Kaipara Harbour the nutrient and water clarity impacts were low at the outermost monitoring sites and became stronger in the inner harbour sites with the strongest impacts localised at the Kaipara River Mouth. This site showed signs of pressures from nutrients and impacted water clarity, confirming previous reporting, modelling results and ecological assessments in the area. However, water quality trend results indicated improvement at promising rates especially for water clarity parameters. These may be measurable by the next state and trends reports as further improvements are expected due to the actions of the Kaipara Moana Remediation Programme.

Overall, our findings highlight both the ongoing local challenges and encouraging signs of improvement in coastal and estuarine water quality, reinforcing the importance of continued monitoring to support management efforts to protect and enhance Tāmaki Makaurau's/Auckland's coastal environments.

10.1 Next steps and recommendations

Our reporting has provided insights into state and trends in coastal water quality across Tāmaki Makaurau / Auckland. Two key knowledge gaps remain which limits our ability to support effective management and to meet the monitoring objectives outlined in Section 1.2.:

1. Understanding the extent of nutrient enrichment and its ecological consequences.
2. Identifying the drivers of change.

Firstly, signs of nutrient pressure were observed at locations such as the upper Waitematā Harbour, Manukau Harbour, Kaipara River Mouth, and potentially the upper inlets of the Tāmaki Estuary. However, we could not determine the severity of ecological impacts. Nutrient guideline exceedances, while observed, do not fully reflect nutrient enrichment because nutrients may be rapidly assimilated by microalgae, resulting in low measurable nutrient concentrations even in nutrient-rich systems (Stevens et al., 2024). Monthly monitoring is unlikely to detect peak phytoplankton growth due to daily and seasonal bloom cycles. To improve understanding of bloom frequency and duration, high-frequency chlorophyll *a* monitoring should be considered in estuaries with potential nutrient pressures.

Similarly, dissolved oxygen is an essential indicator for nutrient enrichment but varies over daily, seasonal, and spatial scales (Stevens et al., 2024). Our monthly daytime surface monitoring likely missed critical low dissolved oxygen events, which typically occur at night or near the seabed. Continuous dissolved oxygen monitoring for estuaries would be useful where current discrete monitoring suggests nutrient pressures affecting oxygen concentrations.

Our analysis suggests that observed changes are likely influenced by a combination of factors, including climate-related events (e.g. the 2022/23 heavy rainfall, marine heatwaves), freshwater inputs, mixing with marine waters, and land use changes. Addressing the second knowledge gap—identifying drivers of change—requires understanding the influence of these different factors. An important step is quantifying freshwater nutrient and sediment loads into estuaries under different climate conditions, accounting for seasonal and inter-annual variability. Monitoring water quality and flow rates at terminal river reaches would provide data to enabling accurate load estimates, improving modelling of land-use impacts, and guiding management responses (Dudley et al., 2024). This is particularly important in areas with potential nutrient pressures. Additionally, understanding open coastal and oceanic impacts is important for the overall understanding of drivers of change in water quality (Dudley et al., 2024). The current monitoring programme does not include information from the southern Hauraki Gulf, or open coastal data from the west coast. Implementing monitoring would provide better understanding of oceanic impacts on coastal water quality.

In summary, to strengthen future monitoring and reporting we recommend:

- Confirming water quality trend results once a longer, more consistent data record is available and/or investigate alternative methods for trend analysis that can account for method changes.
- Reviewing localised water quality guidelines and the methods for the water quality index under consideration of methodological changes.
- Investigating the use of high-frequency chlorophyll *a* and dissolved oxygen monitoring at estuaries with suspected nutrient pressures to better understand the current extent of nutrient enrichment.
- Exploring options to monitor freshwater quality and flow at terminal river reaches to quantify nutrient and sediment loads into coastal receiving waters.
- Consider monitoring options for the southern Hauraki Gulf and offshore sites to understand marine influences on coastal water quality.

These steps will improve our ability to detect, interpret, and respond to coastal water quality changes, and help link them to their underlying drivers.

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Appendix A: Analytical methods for water quality parameters

Table A-1. Water quality analytical methods – field parameters.

Group	Parameter	Units	Field Equipment/ 2010-2014	Detection Limit	Equipment 2014*-current	Detection Limit
Physical	Dissolved oxygen saturation	% sat	YSI 556	0	EXO sonde, optical method	0
Physical	Dissolved oxygen	mg/L	YSI 556	0	EXO sonde, optical method	0
Physical	Temperature	°C	YSI 556	-5	EXO sonde, thermistor	-5
Physical	Conductivity	mS/cm	YSI 556	0	EXO sonde, 4-electrode nickel cell	0
Physical	Salinity	ppt	YSI 556	0	EXO sonde, 4-electrode nickel cell	0
Physical	pH	pH units	YSI 556	0	EXO sonde, glass combination electrode	0
Clarity	Turbidity	FNU	NA	NA	EXO sonde, optical 90° scatter	0

Table A-2. Water quality analytical methods – field parameters.

Group	Parameter	Units	Watercare Laboratory Services 2010-July 2017		Hills Laboratory August 2017-Current	
			Methods	Detection Limit	Method	Detection Limit
Clarity	Total suspended solids	mg/L	APHA (2005/2012) 2540 D	0.2	APHA (2017) 2540 D 22nd ed.	3
Clarity	Volatile suspended solids	mg/L	NA	NA	APHA 2540 E (modified) (from July 2024)	3
Clarity	Turbidity	NTU	APHA (2005/2012) 2130 B (modified)	0.05	APHA (2012/2017) 2130 B (modified) 22nd/ 23rd ed.	0.05
Nutrients	Ammoniacal nitrogen	mg N/L	APHA (2005/2012) 4500-NH3 G (modified), APHA (online edition) 4500-NH3 H (from July 2016)	0.005	APHA (2017) 4500-NH3 H (modified) 23rd ed.	0.005
Nutrients	Total oxidised nitrogen	mg N/L	APHA (2005/2012) 4500-NO3 F (modified), APHA (online edition) 4500-NO3 I (from July 2016)	0.002	APHA (2012/2017) 4500-NO3 I 22nd /23rd ed.	0.001
Nutrients	Total nitrogen	mg N/L	APHA (2005/2012) 4500-P J, 4500-NO3 F (modified), APHA (online edition) 4500-P J (modified),4500- NO3 I (from July 2016)	0.02, 0.01 (from Sept 2015)*	APHA (2017) 4500-N C & 4500-NO3 I (modified) 22nd/ 23rd ed	0.01

Nutrients	Nitrate nitrogen	mg N/L	(Nitrate-N + Nitrite-N) - Nitrite-N	0.002	(Nitrate-N + Nitrite-N) - NO2N	0.001
Nutrients	Nitrite nitrogen	mg N/L	APHA (2005/2012) 4500-NO2 B (modified)	0.002	APHA (2012/2017) 4500 NO3 I 22nd /23rd ed (modified)	0.001
Nutrients	Total Kjeldahl nitrogen	mg N/L	Calculation	0.02	Calculation: TN - (NO3N + NO2N)	0.01
Nutrients	Dissolved reactive phosphorus	mg P/L	APHA (2005/2012) 4500-P B, F (modified), APHA (2012) (online edition) 4500-P F (from October 2015)	0.005, 0.002 (from Sept 2014)	APHA (2017) 4500-P G (modified) 22nd/23rd ed	0.004, 0.001 (from May 2018)
Nutrients	Total phosphorus	mg P/L	APHA (2005/2012) 4500-P B, J (modified), APHA (2012) (online edition) 4500-P J (modified) (from October 2015)	0.005, 0.004 (from Sept 2014)	APHA (2012/2017) (online edition) 4500-P B & E (modified) 22nd/23rd ed, APHA (2017) 4500-P H (modified) 23rd ed (from December 2020)	0.004
Algae	Chlorophyll α	mg/L	APHA (2005/2012) 10200 H (modified) Spectroscopy	0.0006	APHA (2012/2017) 10200 H (modified) 22nd/23rd ed. Flurometry, APHA (2017) 10150 C (modified) (from June 2024)	0.003, 0.0002 (from May 2018)
Physical	pH	pH	NA	NA	APHA (2012) 10200 H (modified) 22nd ed. (from August 2018- May 2019), APHA (2017) 4500-H+ B (modified) 23rd ed. (From July 2020)	0.1

**Change in calibration procedure for saline matrix samples – September 2015*

Appendix B: Example timeseries and trend plots for ammoniacal nitrogen indicating the presence of step changes in coastal water quality monitoring data

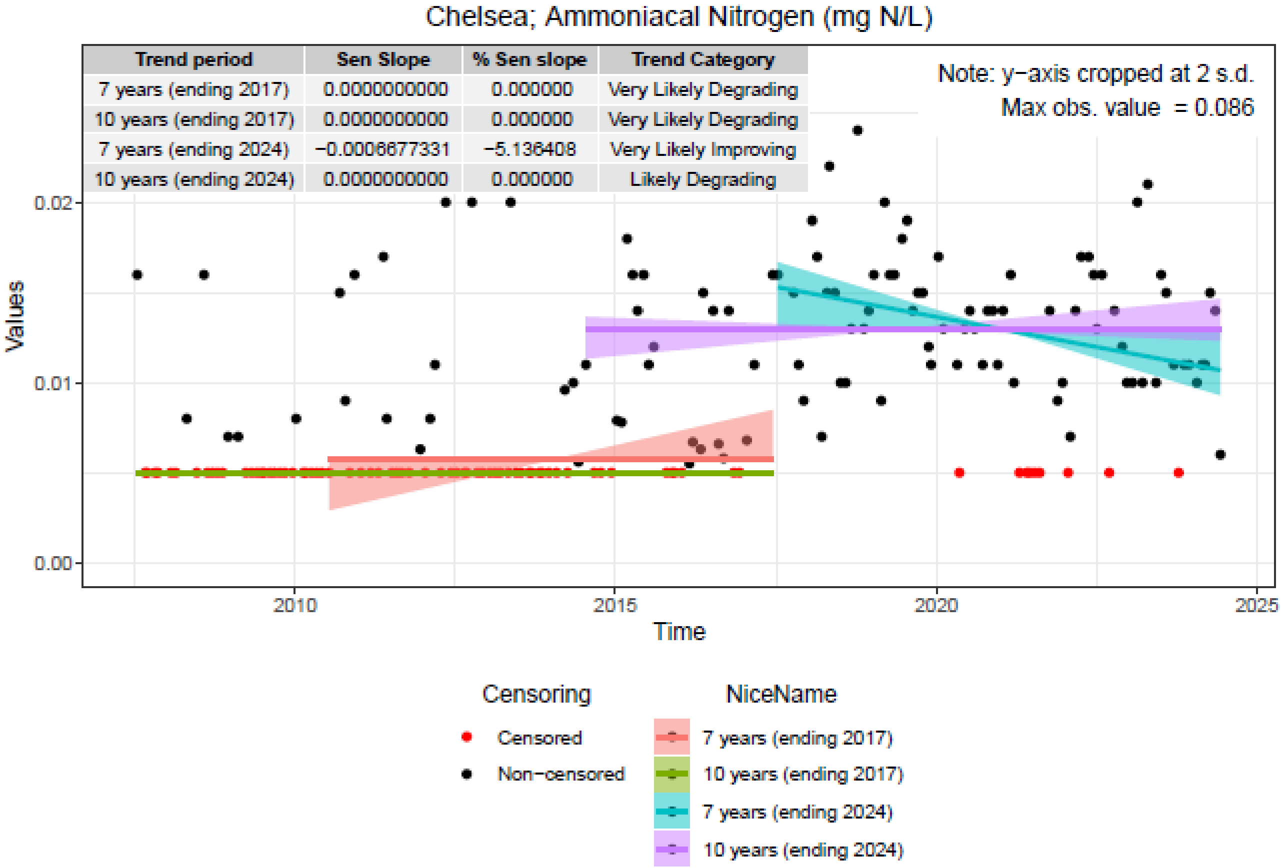

Figure B-1. Trend plots for ammoniacal nitrogen at Chelsea water quality monitoring sites for 7 years and 10 years before and after the change in laboratories in July 2017.

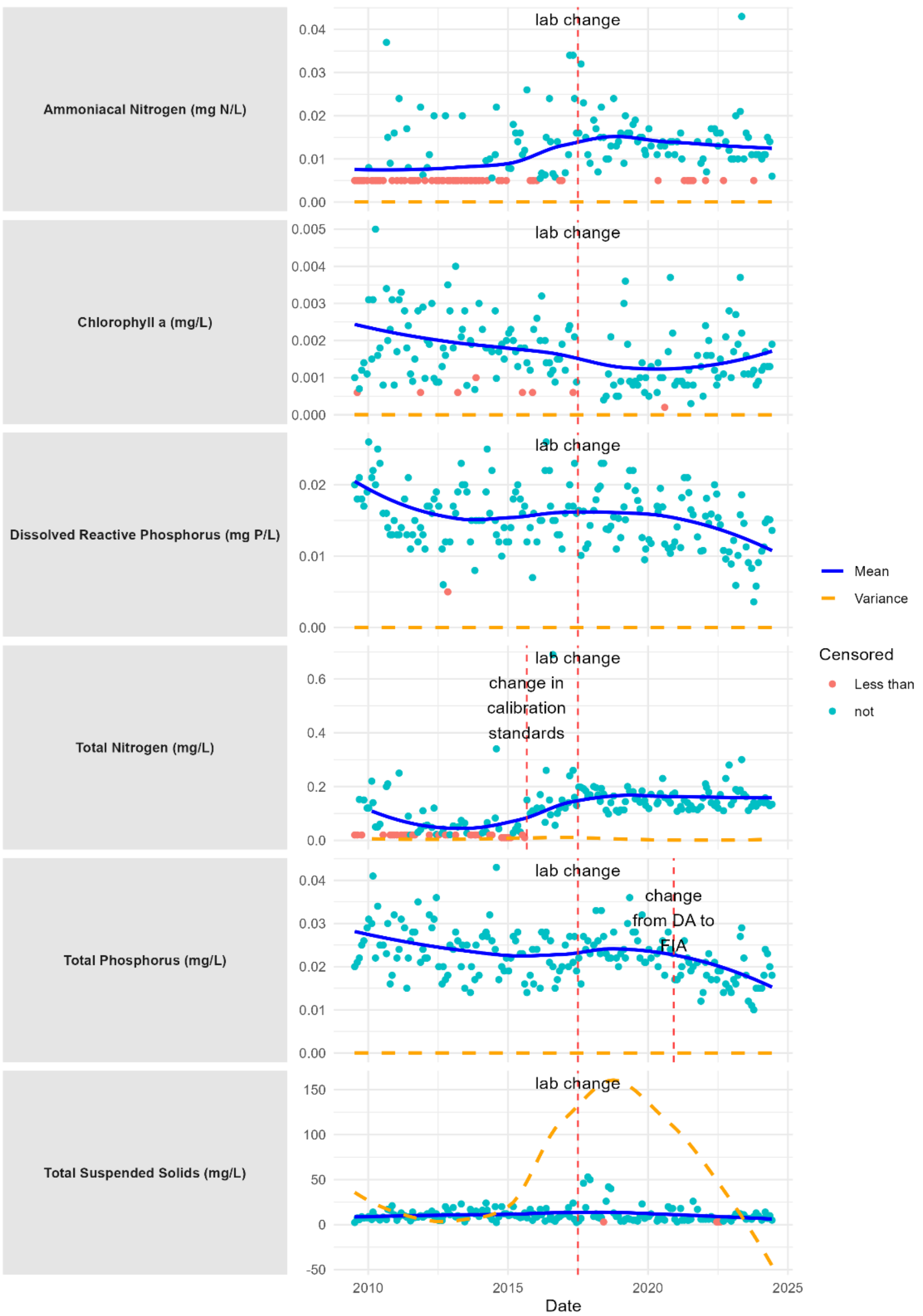

Figure B-2. Time series plot for all parameters with known or suspected step-changes at Chelsea water quality monitoring site.

Appendix C: Supplementary Data Files

Supplementary data file 1: Coastal and estuarine water quality state results (2020 to 2024): Available on Knowledge Auckland.

Supplementary data file 2: Water quality trends results for all analysis periods ending June 2024. See Snelder and Fraser (2025) for a detailed description of contents. Available on Knowledge Auckland.

Appendix D: Monthly box plots statistics with water quality guidelines

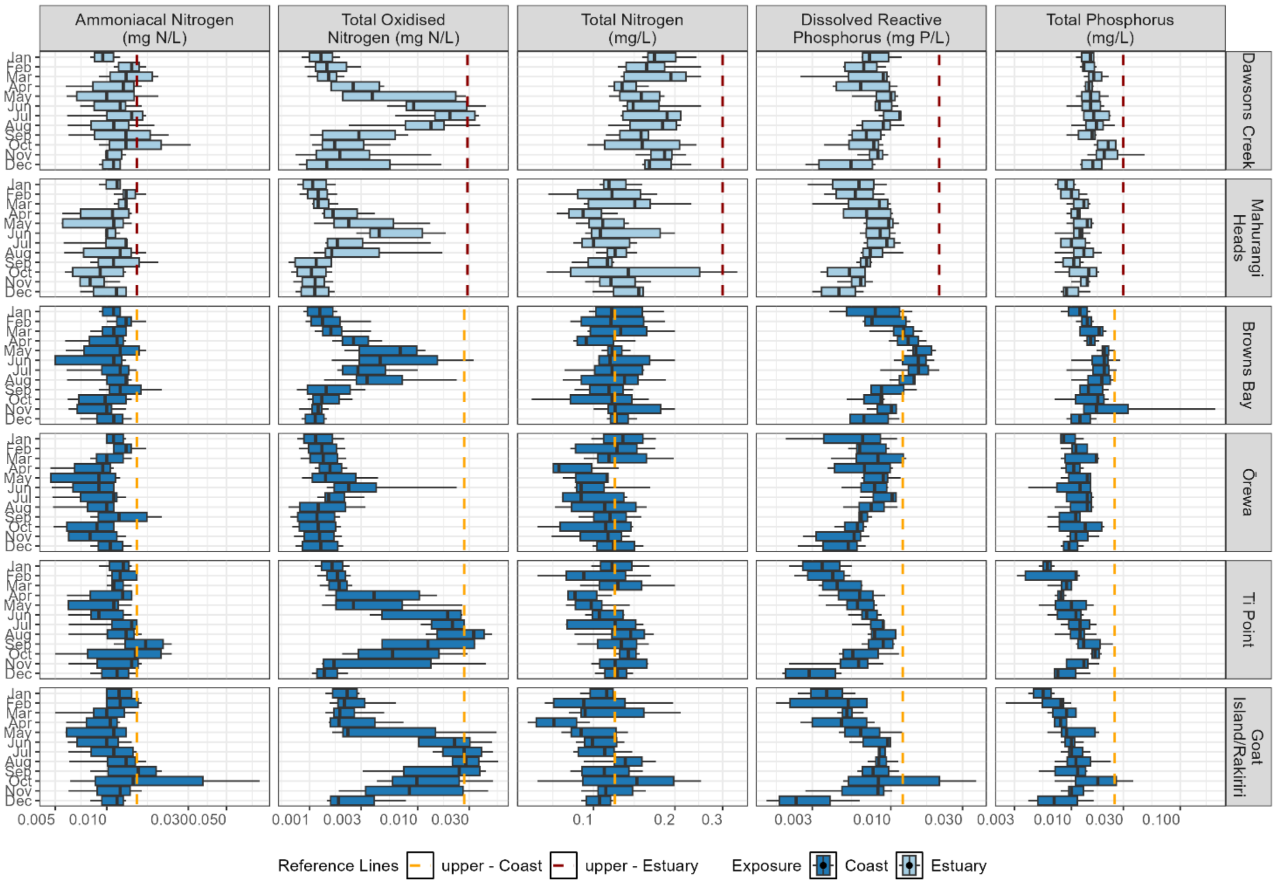

Figure D-1. Monthly statistics for nutrient parameters for the 2020 to 2024 period at East Coast monitoring sites. The x-axis is shown at log scale. Guidelines values as per Table 2-2.

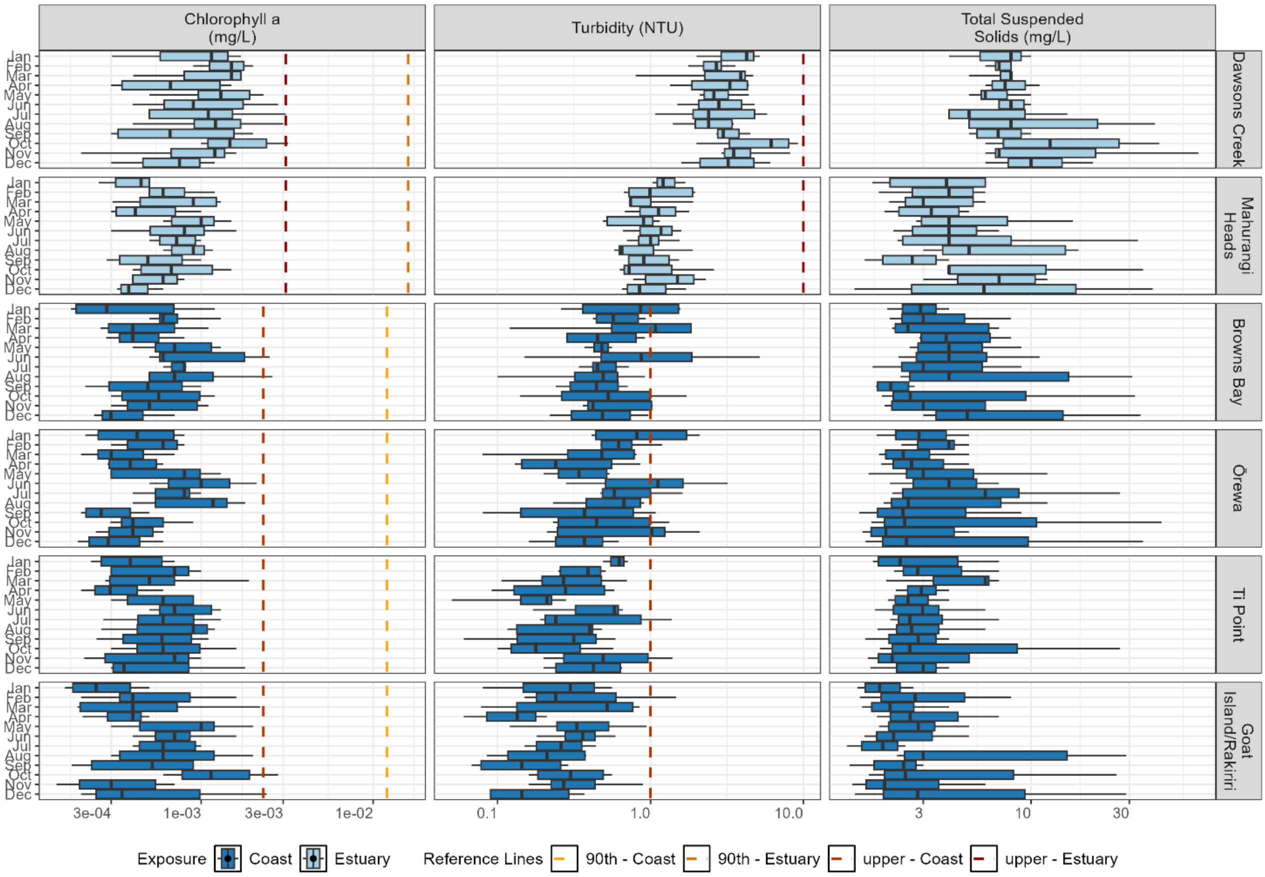

Figure D-2. Monthly statistics for water clarity parameters for the 2020 to 2024 period at East Coast monitoring sites. The x-axis is shown at log scale. Guidelines values as per Table 2-2.

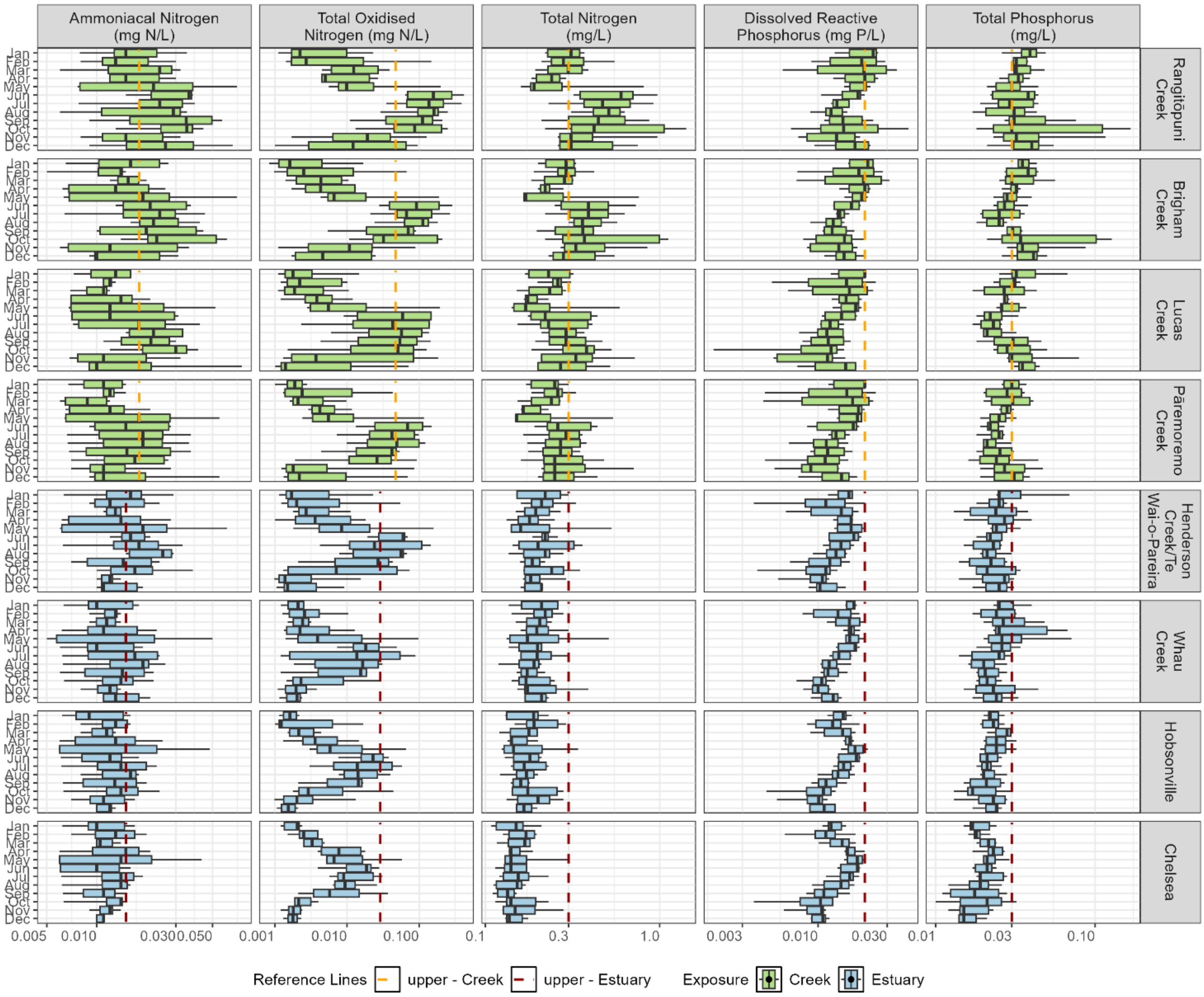

Figure D-3. Monthly statistics for nutrient parameters for the 2020 to 2024 period at Waitematā monitoring sites. The x-axis is shown at log scale. Guidelines values as per Table 2-2.

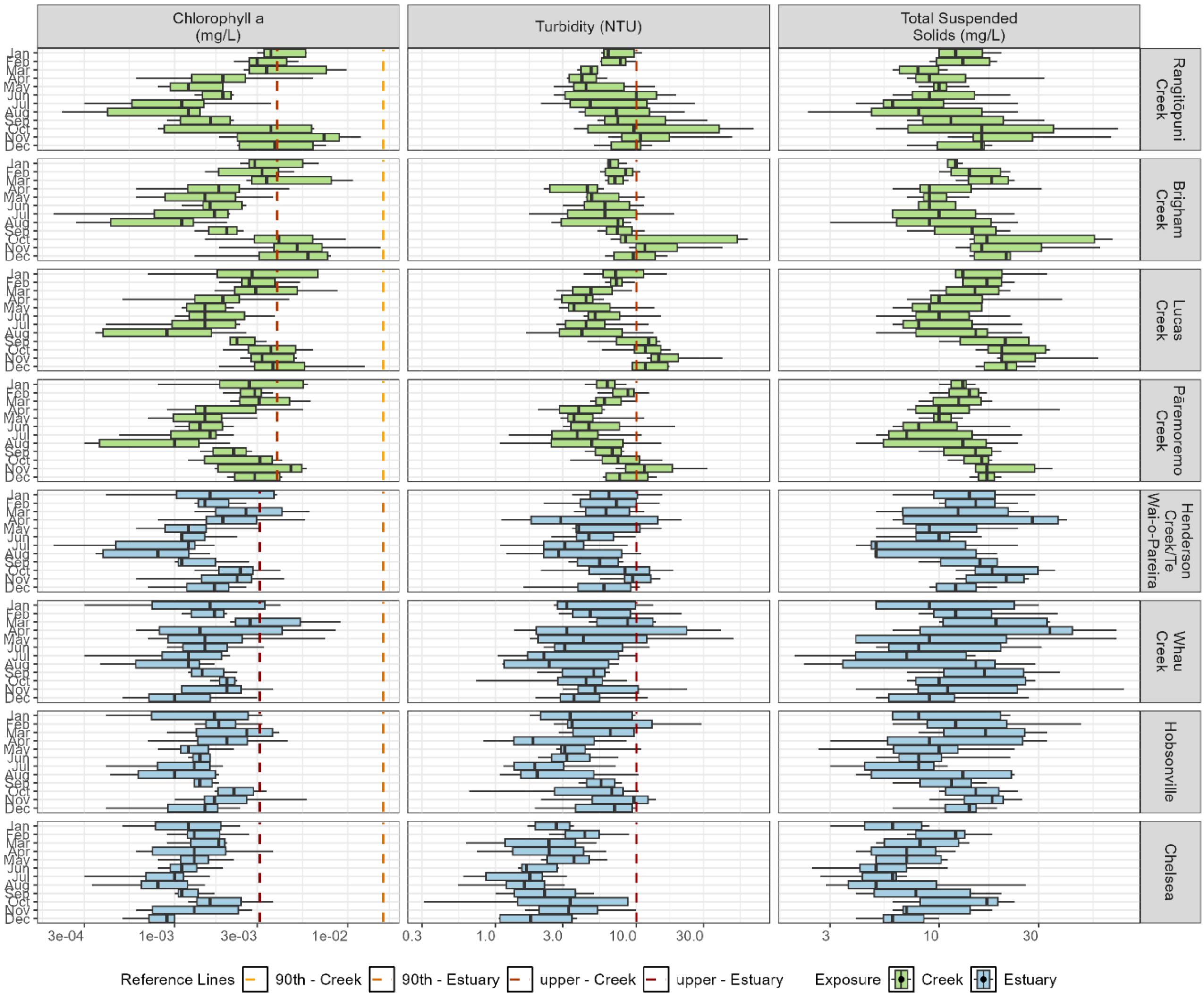

Figure D-4. Monthly statistics for water clarity parameters for the 2020 to 2024 period at Waitematā monitoring sites. The x-axis is shown at log scale. Guidelines values as per Table 2-2.

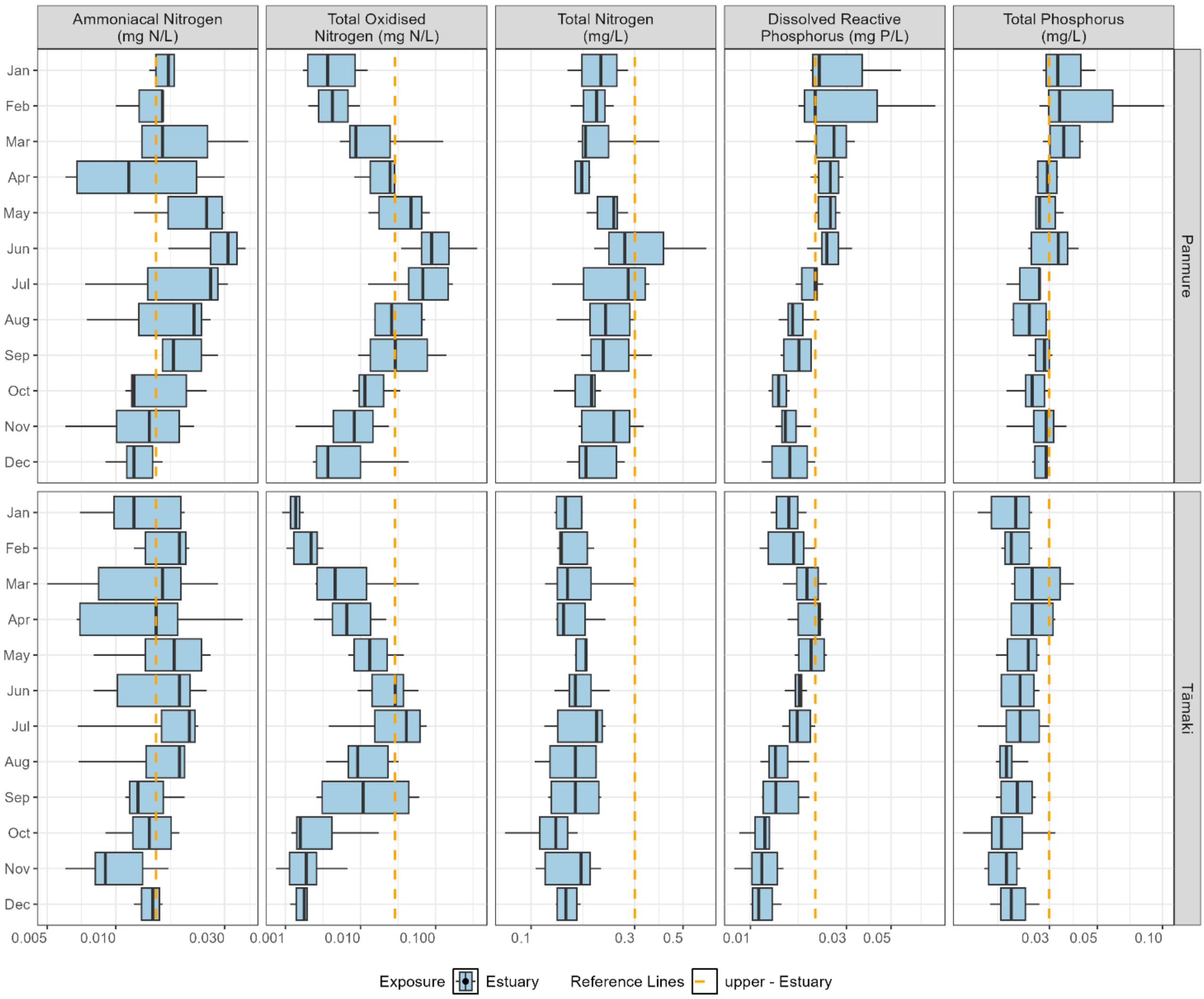

Figure D-5. Monthly statistics for nutrient parameters for the 2020 to 2024 period at Tāmaki Estuary monitoring sites. The x-axis is shown at log scale. Guidelines values as per Table 2-2.

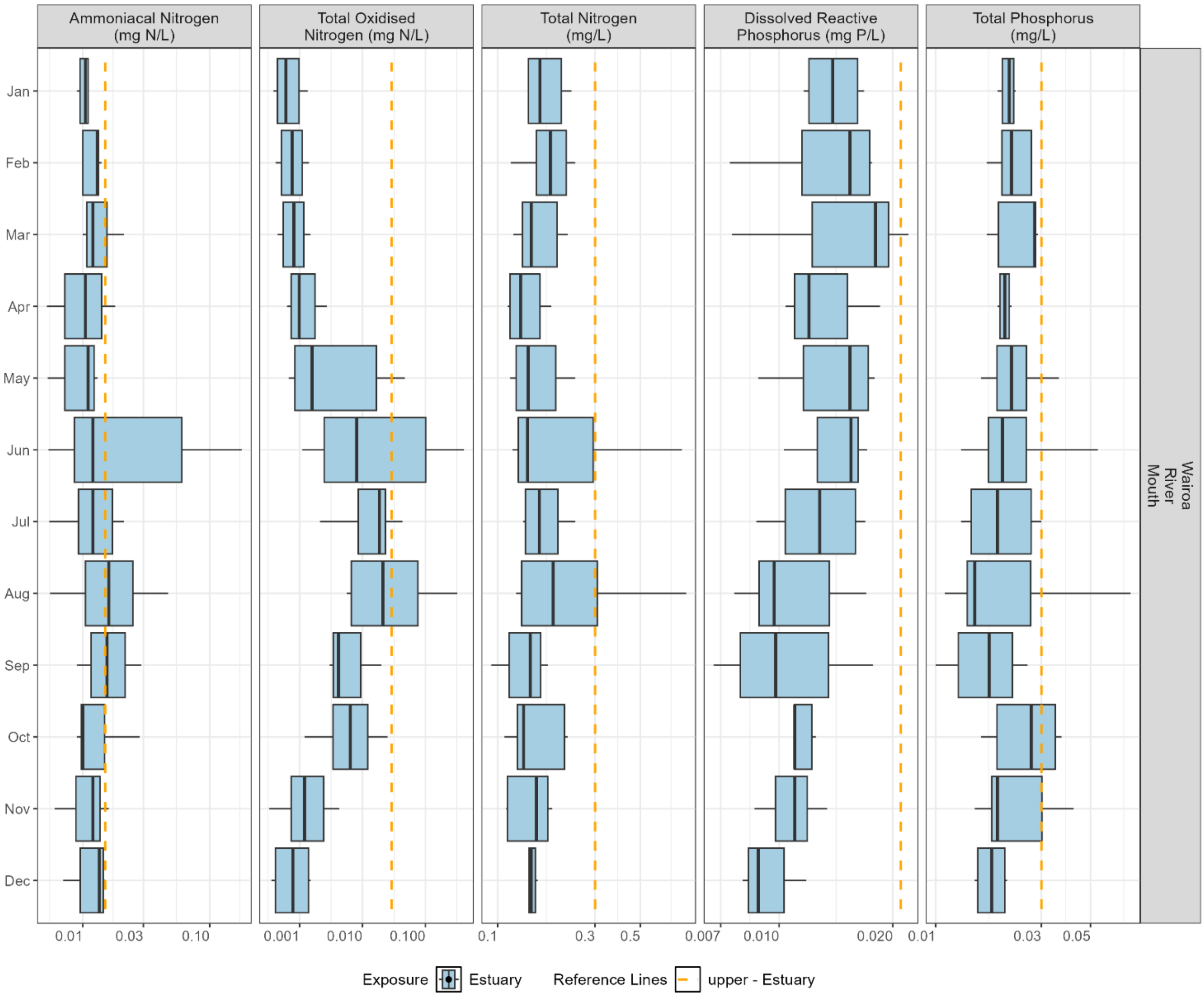

Figure D-6. Monthly statistics for nutrient parameters for the 2020 to 2024 period at Wairoa River Mouth. The x-axis is shown at log scale. Guidelines values as per Table 2-2.

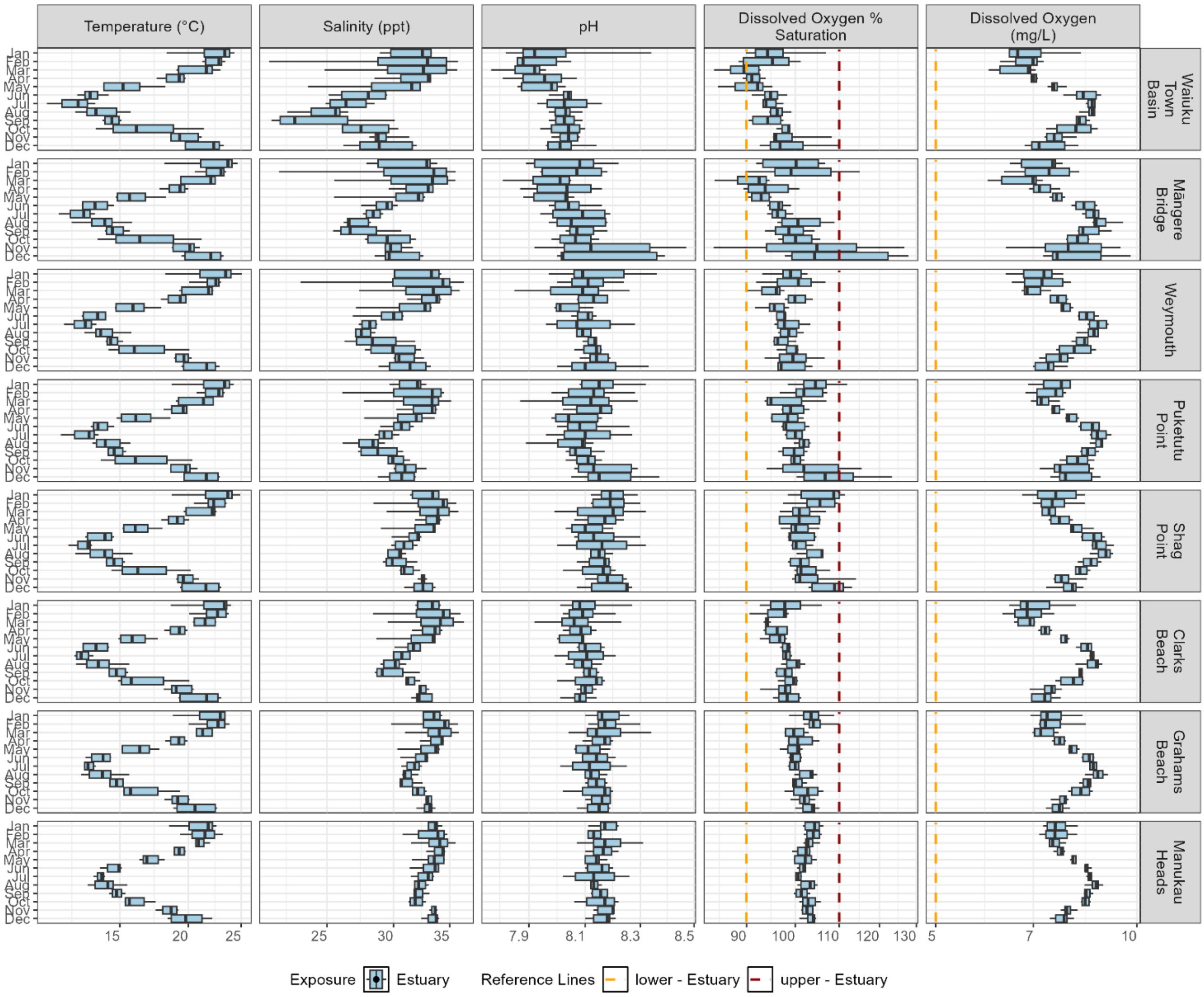

Figure D-7. Monthly statistics for physical parameters for the 2020 to 2024 period at Manukau Harbour monitoring sites. The x-axis is shown at log scale. Guidelines values as per Table 2-2.

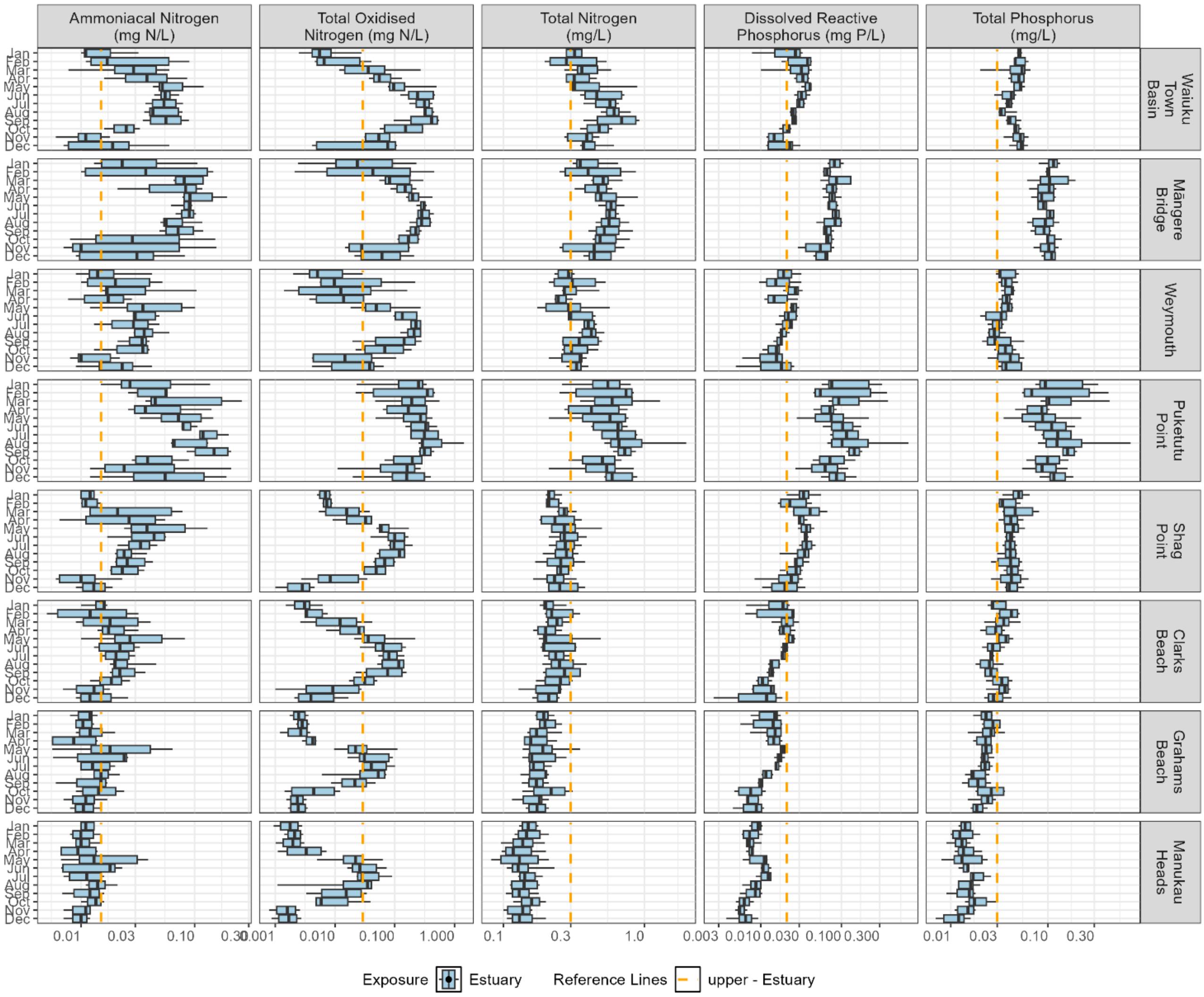

Figure D-8. Monthly statistics for nutrient parameters for the 2020 to 2024 period at Manukau Harbour monitoring sites. The x-axis is shown at log scale. Guidelines values as per Table 2-2.

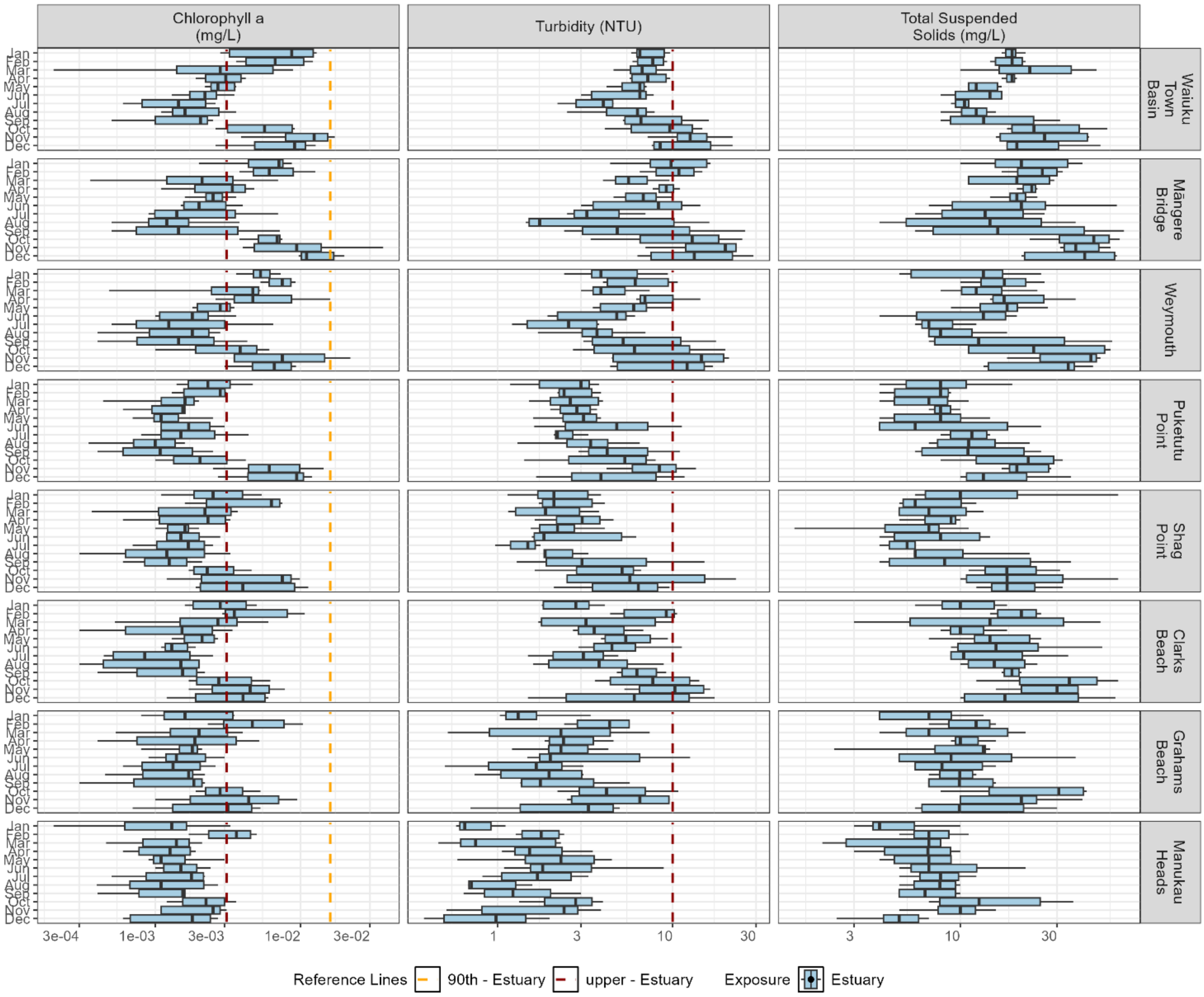

Figure D-9. Monthly statistics for water clarity parameters for the 2020 to 2024 period at Manukau Harbour monitoring sites. The x-axis is shown at log scale. Guidelines values as per Table 2-2.

Figure D-10. Monthly statistics for nutrient parameters for the 2020 to 2024 period at Kaipara Harbour monitoring sites. The x-axis is shown at log scale. Guidelines values as per Table 2-2.

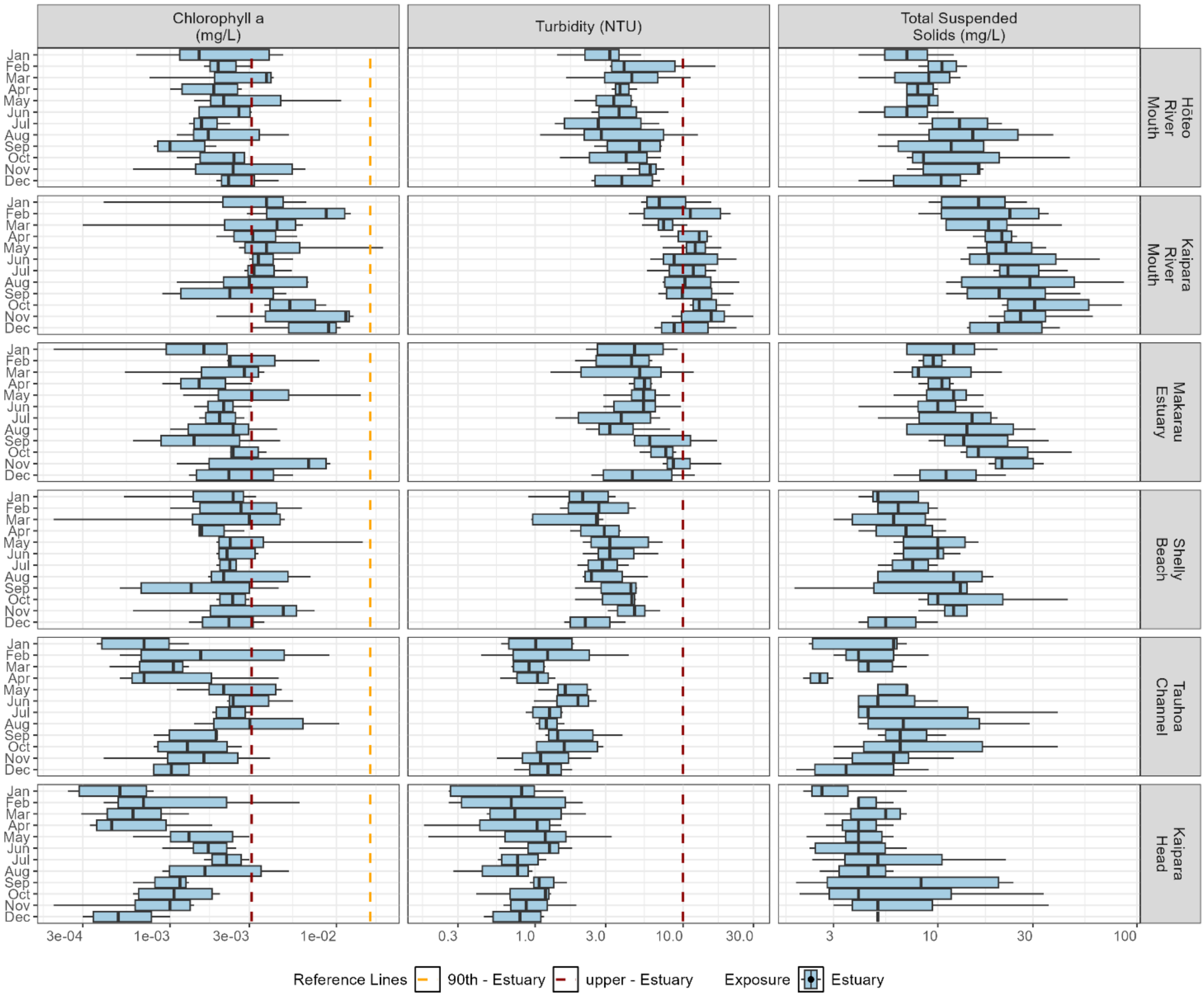

Figure D-11. Monthly statistics for water clarity parameters for the 2020 to 2024 period at Kaipara Harbour monitoring sites. The x-axis is shown at log scale. Guidelines values as per Table 2-2.

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